REPORT for

American Institute of Chemical Engineers
(AIChE)

Pulp and Paper Industry
Energy Bandwidth Study

Prepared by

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1. INTRODUCTION

The American Institute of Chemical Engineers (AIChE) has been requested to manage a Project, on behalf of the Department of Energy's Industrial Technologies Program (DOE-ITP), to develop estimates of the present energy consumption of the U.S. Pulp and Paper Industry and how much energy could be saved if more efficient types of pulp and paper manufacturing technologies as well as best practices were employed. Specifically, the energy estimates of the following cases were requested:

- An estimate of the current average energy consumption by mill areas / technologies based on the 2002 Manufacturing Energy Consumption Survey (MECS),
- An estimate of what the energy consumption would be by mill areas / technologies if "Best Available" practices were applied, i.e. current state-of-the-art (SOA) or Best Available Technologies (BAT),
- An estimate in selected mill areas / technologies of what the energy consumption would be if new technologies could be developed to drive energy consumption down to "practical minimum" using advanced technology not currently practiced. The difference between today's average and the "practical minimal technologies" represents an area of opportunity that could be used to direct research grant money to encourage the development of technologies that would result in reduced energy consumption, and
- An estimate of what the energy consumption would be of selected mill areas / technologies if "minimum theoretical" energy could be achieved, i.e. the energy use calculated from the first law of thermodynamics.

Jacobs, working in collaboration with the Institute of Paper Science and Technology (IPST) at Georgia Institute of Technology (GT), Atlanta, Georgia has developed the energy distribution matrix within the U.S. Paper Industry. This report outlines those findings.

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2. EXECUTIVE SUMMARY

In 2002 the U.S. Paper Industry produced 99.5 million tons of pulp and paper products while consuming 2,361 trillion Btus. The 2002 Manufacturing Energy Consumption Survey (MECS) data was used for energy consumption since these are the latest government published numbers and these consumption figures match published production data for the same time period. It should be noted that since 2002, the Pulp and Paper Industry has reduced it's energy consumption, primarily through the use of waste energy streams, i.e. capturing the energy in waste heat streams, both air and liquid, as well as installing energy saving devices such as variable speed motors and more efficient lighting. By using data for the same time period (2002) the relative difference between actual and projected energy savings using Best Available Technology (BAT) can be estimated as well as the potential savings using advanced technologies, i.e. Practical Minimums.

The breakdown of fuels used by the Pulp and Paper industry is shown in Figure 2.1. The largest category of fuel used by the industry is black liquor and hog fuel (i.e. bark / wood waste) and represents about 54.3% of the industry's energy input. (These fuel categories are included in the MECS classification as "Other", with black liquor representing 71% of the 'other' category and hog fuel 27%, as shown in Figure 2.2). Natural gas is the second largest category at 21.3% with coal and net electricity at 9.9% and 9.4% respectively. Net electricity amounts to 65,339 million kWh while the industry's on-site generation is 51,208 million kWh, which is 44% of its total electrical requirements.

Figure 2.1

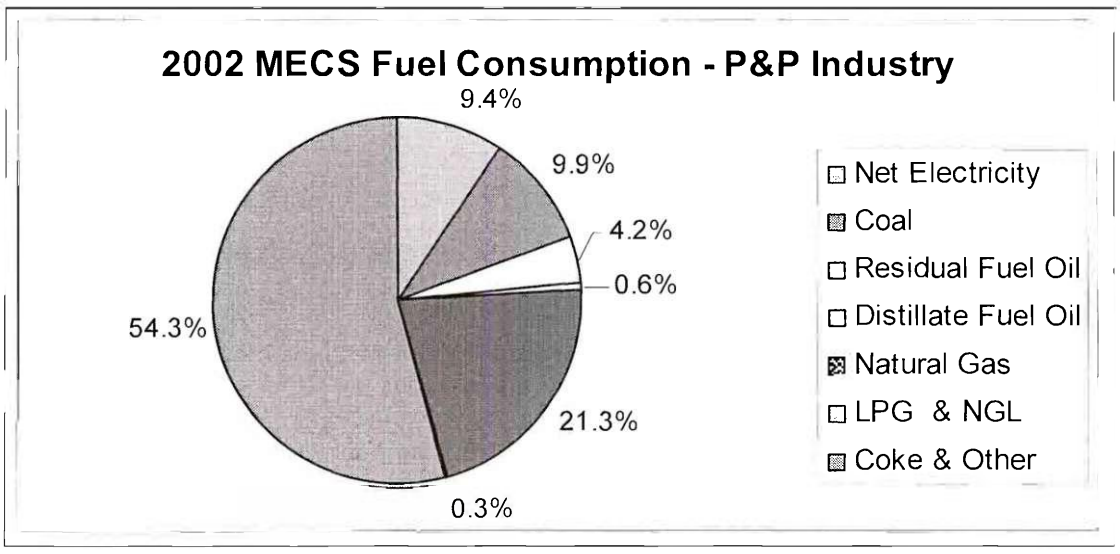
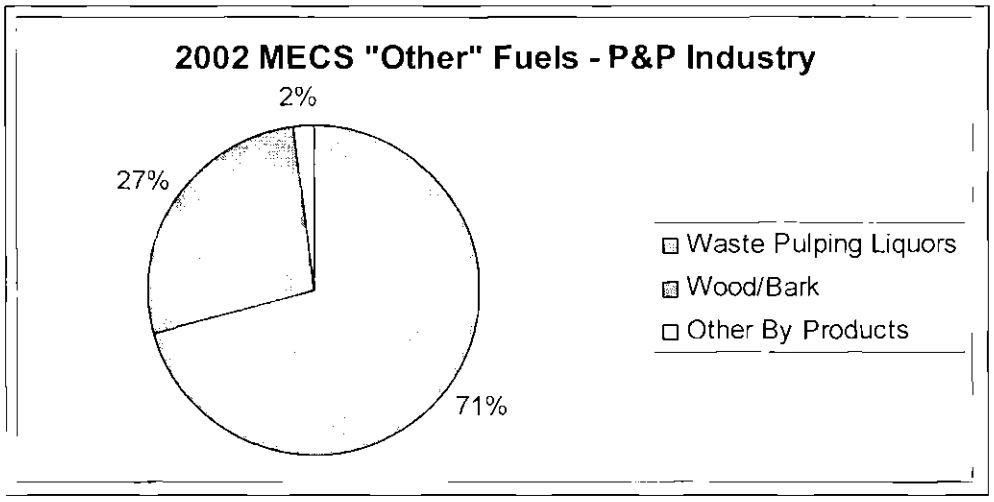


Figure 2.2



In 2002, paper and board production was 89.7 million tons and market pulp production was 9.9 million tons. The largest category of paper products is board (54%), followed by printing and writing paper (20%), mechanical paper grades (13%) and tissue products (8%), as shown in Figure 2.3. In 2002 pulp production was 86.4 million tons. The largest category was bleached kraft (34%), followed by unbleached kraft (23%), as shown in Figure 2.4. Recycled fiber accounted for 33% of the total pulp with old corrugated containers (OCC) being 59% of the total recycle fiber.

Figure 2.3

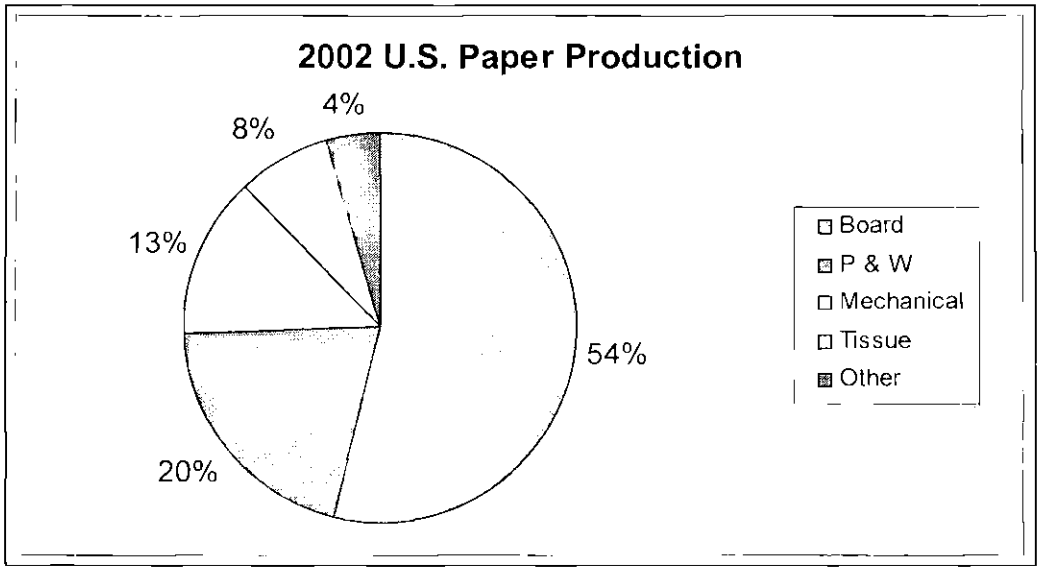
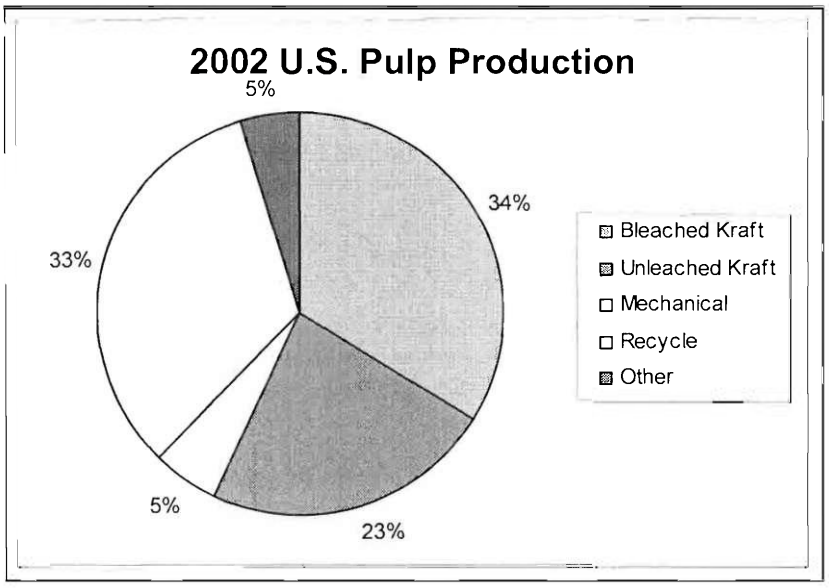


Figure 2.4



This study is production weighted, i.e., the energy consumed is based on the tons of pulp and paper produced by type (kraft, thermo-mechanical pulp (TMP), printing & writing, linerboard, etc.) multiplied by the energy consumed by ton for the various large process areas within a mill. Examples of large process areas are: pulping, bleaching, liquor evaporation, stock preparation, paper drying, etc. As such, even though TMP consumes a large quantity of electric power per unit of pulp produced, total energy consumed is small compared to the energy consumed by the U.S. pulp and paper industry since only a small quantity of TMP is produced in the U.S. This report focuses on the large blocks of energy consumed by the U.S. pulp and paper industry rather than the large process units with relative little impact on the industry's total energy consumption.

The distribution of energy used, based on MECS[1], in the pulp and paper industry is shown in Table 2.1. The energy consumed in the powerhouse is the energy that is lost within the powerhouse due to boiler efficiency, soot blowing, steam venting, turbine and transformer efficiency, etc. and is not the energy that exits the powerhouse and is used in the manufacturing processes.

By applying BAT – current design practices for the most modern mills - energy consumption within the Pulp and Paper Industry can be improved by 25.9% for an annual use estimate of 1,749 TBtu vs. the MECS data of 2,361 TBtu (Table 2.1). Purchased energy, including electric power, changed from 1,109 TBtu (MECS Case) to 597 TBtu (BAT Case), a 46.2% reduction, as shown in Figure 2.9. BAT calculations were based on the MECS energy distribution matrix. Published design unit energy consumptions for new or modern mill designs (vs. MECS unit consumption being "average" for 1990 vintage mills) were used to back calculate

energy consumption. Powerhouse energy efficiencies were raised and energy generated from hog fuel and black liquor remained constant since production remained constant from MECS. Both MECS and BAT are based on energy consumption, which incorporates recovered heat integration. There are many interrelationships between process areas, like between digesting / washing and evaporation that impact energy use. Energy heat recovery is just one of many relationships impacting gross energy consumption. Today's energy efficient mills do recover "waste" heat / energy.

Table 2.1
Energy Use Distribution within the Pulp and Paper Industry

Total MECS vs. Total After Applying BAT

Area	Total Energy Use 2002 MECS TBtu (% of total)	Total Energy Use BAT TBtu (% of total)	BAT Percent Change vs. MECS (%)
Paper Manufacturing	776 (32.9)	527 (30.1)	-32.1
Pulping	708 (30.0)	508 (29.0)	-28.2
Powerhouse Losses	755 (32.0)	592 (33.9)	-21.5
Misc. & Environmental	122 (5.1)	122 (7.0)	0.0
Total Industry Energy Consumption (Purchased and By-product Fuels)	**2,361** (100.0)	**1,749** (100.0)	**-25.9**

The energy use for manufacturing pulp and paper, by type (direct fuel, electricity and steam), is shown in Table 2.2. Powerhouse loses in co-generation of the steam and electricity needed for the manufacturing processes account for the remaining energy consumed in the industry. Energy use by type within the pulp and paper manufacturing, after applying BAT, is also shown in Table 2.2.

The six major consumers by area within Pulp and Paper manufacturing are shown in Table 2.3. These six areas account for 84.6% (1,256 TBtu) of the 1,606 TBtu used in manufacturing under MECS and 83.1% (860 TBtu) of the 1,157 TBtu with BAT.

Paper drying and liquor evaporation, shown in Table 2.3, are self-explanatory. Paper Machine Wet End is the energy consumed in stock preparation ahead of the

paper machine and, includes refining, cleaning and screening, pumping of stocks, forming and pressing, etc. Pulping Chemical Preparation is the energy used in the pulp mill for chemical preparation, such as white liquor, and includes energy consumed in the lime kiln. Wood cooking is the energy consumed in the cooking of chemical pulps (sulfite, kraft and NSSC) and does not include the energy used for refining and grinding in the preparation of mechanical pulps, e.g. stone groundwood and TMP.

Table 2.2
Energy Use by Type within the Pulp and Paper Manufacturing

Total MECS vs. Total After Applying BAT

Type	Total Energy Use by Type 2002 MECS TBtu (% of Total)	Total Energy Use by Type BAT TBtu (% of Total)	BAT Percent Change vs. MECS (%)
Direct Fuel	132 (8.2)	104 (9.0)	-21.1
Electricity	393 (24.5)	297 (25.7)	-24.4
Steam	1,081 (67.3)	756 (65.3)	-30.1
Total Manufacturing	**1,606** (100.0)	**1,157** (100.0)	**-28.0**
Powerhouse Losses	755	592	-21.5
Total Industry	**2,361**	**1,749**	**-25.9**

Table 2.3
Major Energy Users by Area within the Pulp and Paper Manufacturing
Total MECS vs. Total After Applying BAT

Area	Total Energy Use by Area 2002 MECS TBtu (% of Total)	Total Energy Use by Area BAT TBtu (% of Total)	BAT Percent Change vs. MECS (%)
Paper Drying	481 (32.4)	354 (34.2)	-26.4
Paper Machine Wet End	211 (14.2)	95 (9.2)	-54.9
Liquor Evaporation	195 (13.1)	171 (16.5)	-12.1
Pulping Chemical Prep	140 (9.5)	84 (8.1)	-40.1
Wood Cooking	149 (10.0)	101 (9.8)	-32.1
Bleaching	80 (5.4)	55 (5.3)	-31.3
Process Sub Total	**1,256** (84.6)	**860** (83.1)	**-31.5**
Other Processes	228 (15.4)	175 (16.9)	-23.4
Total Process	**1,484** (100.0)	**1,035** (100.0)	**-30.3**
Environmental & Utilities	122	122	0.0
Total Manufacturing	**1,606**	**1,157**	**-28.0**

Overall kraft pulping, bleached and unbleached, which accounts for 57% of the pulp production, accounts for 78% of the energy consumed for pulp production. Board and printing and writing grades, which combined account for 71% of the paper production (51% and 20% respectively), account for 66% of the energy consumed in paper manufacturing (47% and 19% respectively).

Figures 2.5, 2.6 and 2.7 graphically show the comparison of current energy consumption vs. BAT, Practical Minimum and Theoretical Minimum energy

consumption for paper drying, liquor evaporation and lime kiln, respectively. The potential energy savings, i.e. bandwidth, between BAT and Practical Minimum are: Paper Drying – 66%, Liquor Evaporation – 27% and Lime Kiln – 35%. Paper Drying shows the largest gap and potential energy reduction.

Figure 2.5

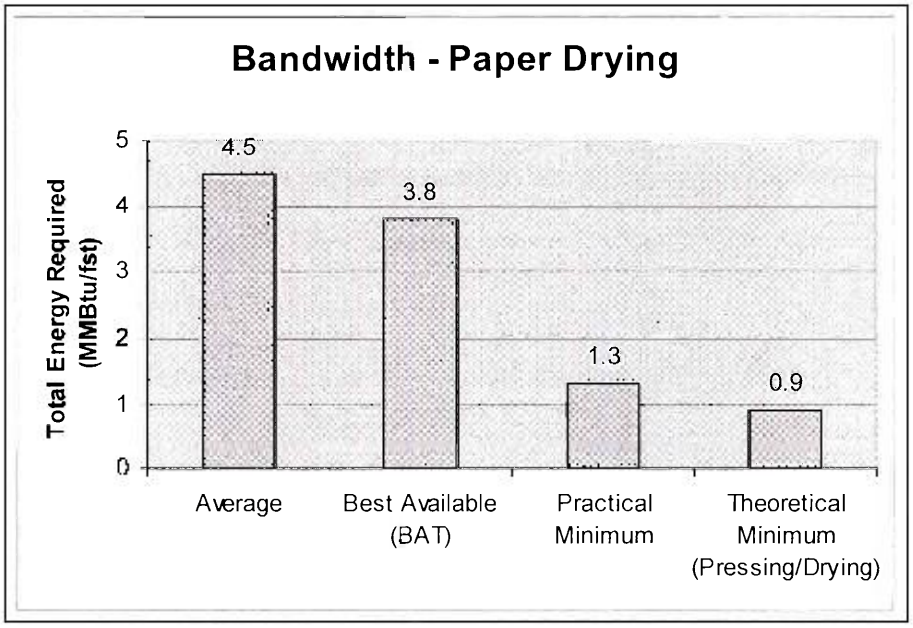


Figure 2.6

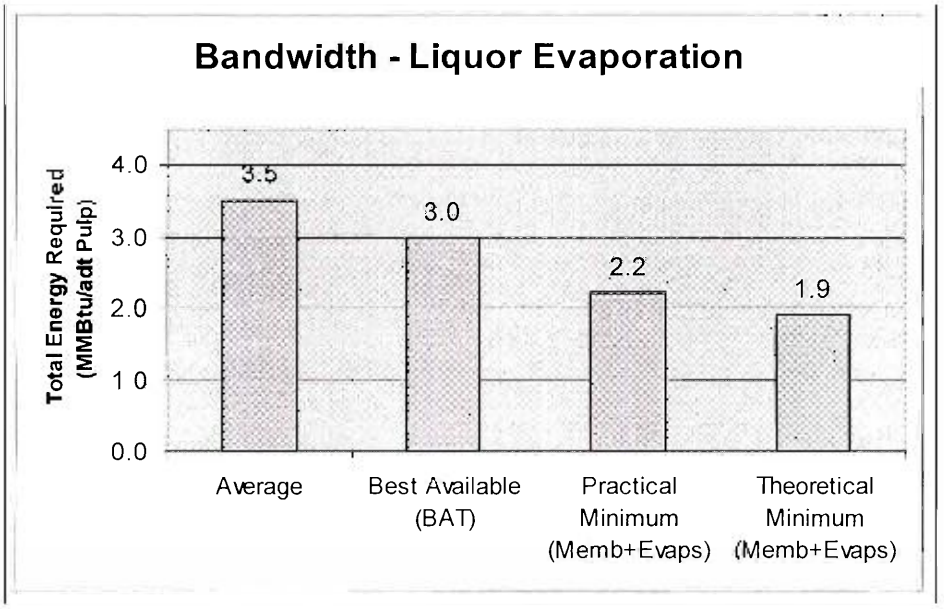


Figure 2.7

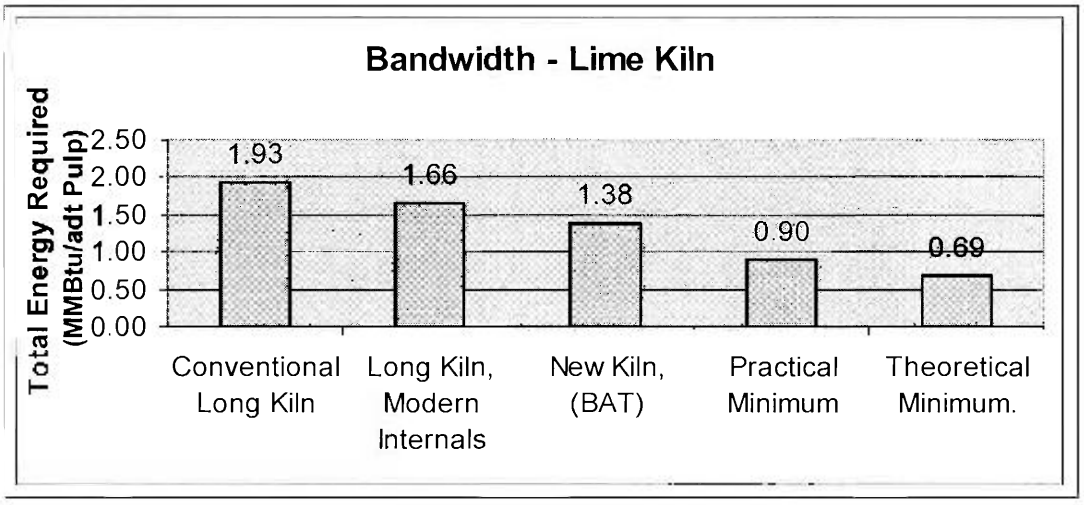


Figure 2.8 and Table 2.4 compares energy consumption using various applied technologies. In Figure 2.8, Practical Minimum and Theoretical Minimum reflect changes in paper drying, liquor evaporation and lime kiln direct fuel reflected in Figures 2.5, 2.6 and 2.7. No other changes have been made.

Figure 2.8

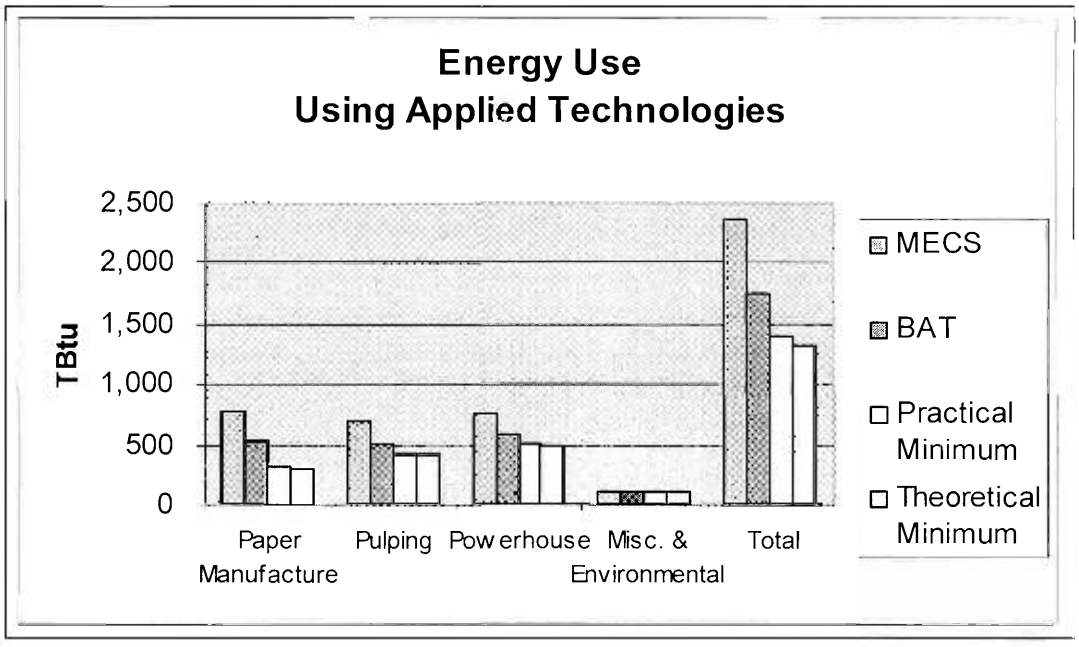
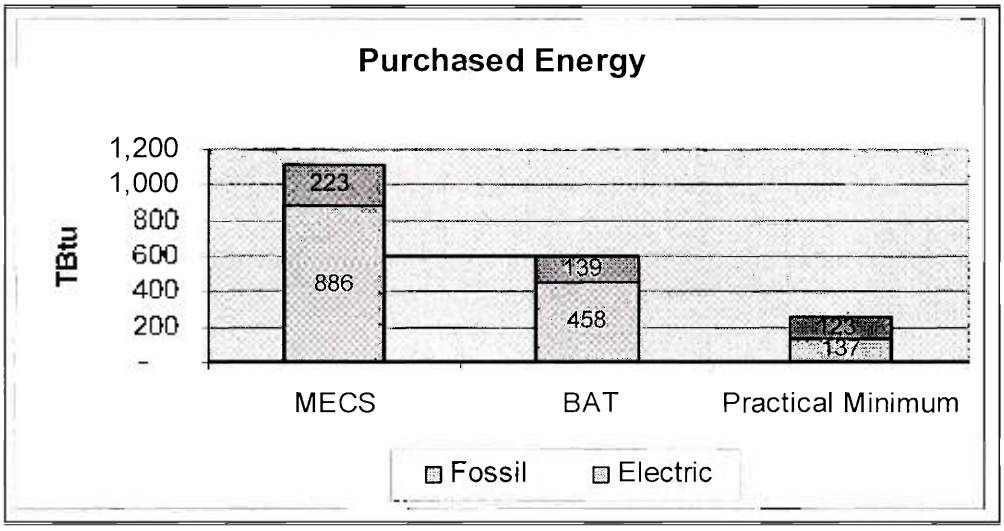


Table 2.4
Energy Use - Using Applied Technologies
(TBtu)

Area	MECS	BAT	Practical Minimum	Theoretical Minimum
Paper Manufacturing	776	527	329	298
Pulping	708	508	441	414
Powerhouse Losses	755	592	508	494
Misc. & Environmental	122	122	122	122
Total Energy	**2,361**	**1,749**	**1,400**	**1,328**

Figure 2.9 shows the impact on purchased fuels by applying BAT and the three Practical Minimum technologies shown above. Shown is a 48% reduction in purchased Fossil fuel between MECS and BAT and 84% reduction between MECS and Practical Minimum, reduction in total purchased energy are 46% and 77% respectively. Additional research (and deployment of technologies) to reduce these and other large energy use areas within the Pulp and Paper Industry will allow the industry to be a net exporter of energy rather than a consumer.

Figure 2.9



3. DOMESTIC ENERGY CONSUMPTION AND PRODUCTION

Paper Industry Energy Consumption Background

The Paper Industry (NAICS Code 322) in the United States used approximately 2,361 trillion Btus[1] (TBtu) while producing approximately 99 5 million tons[2] of pulp and paper products in 2002 (Table 3.1).

Table 3.1

2002 MECS Table 3.2
Energy Consumed
Paper Industry, NAICS 322

	TBtu	%
Net Electricity	223	9.4
Coal	234	9.9
Residual Fuel Oil	100	4.2
Distillate Fuel Oil	13	0.6
Natural Gas	504	21.3
LPG & NGL	6	0.3
Coke and Other	1,281	54.3
Total Energy	**2,361**	**100.0**

The "Coke & Other" category above is largely byproduct fuels used as fuel and on-site electrical generation, as shown in Table 3.2. "Net Electricity" above, 223 TBtu (65,358 million kWh[1]), is obtained by summing the purchases, transfers in and generation from noncombustible renewable resources, minus quantities sold and transferred out. It does not include electricity inputs from onsite co-generation or generation of combustibles fuels because that energy has already been included in generating fuel (e.g. coal, hog or black liquor). On-site generation has been taken into account separately (Table 3.3).

[1] 3412 Btus per Kilowatt-hour

Table 3.2 2002 MECS Table 3.5 Selected By-Products Paper Industry, NAICS 322	
Type	**TBtu**
Waste Gas	1
Waste Pulping Liquors	820
Wood and Bark	316
Other By Products	21
Total	**1,158**

Table 3.3 2002 MECS Table 11.3 Components of On-site Generation Paper Industry, NAICS 322	
Component	**Million kWh**
Cogeneration	45,687
Renewable, except wood & biomass	2,243
Other	3,278
Total On-site Generation	**51,208**

These tables from the MECS served as the basis for the paper industry energy consumption in the current bandwidth study. Additionally, the numbers were checked against the energy[3] consumption figures reported by American Forest and Paper Association (AF&PA) in the 2002 Statistics Report (Table 3.4), which show close agreement with the DOE MECS numbers. AF&PA did not report energy in the 2004 Statistical Report, so the 2002 Statistical Report figures were used. Neither database covers the complete paper industry and the accuracy of the data is dependent upon the effort the reporting companies invested in collecting the data. The MECS is based on companies that respond to the survey. AF&PA data is generally limited to AF&PA member companies, although some non-member companies have given AF&PA information, and not all member companies provide information to AF&PA. The two different databases agree closely with a difference of about 8%. Production in 2000 was 105.6 million tons vs. 2002 production of 99.5 million tons, a 5.8% change, which account for much of the difference. As a sanity

check, the AF&PA and MECS numbers were checked against Paperloop's (now RISI) Analytical Cornerstone®[4] database which reports purchased energy consumed by the paper industry. The check did not show any significant difference and validated the AF&PA and MECS purchased energy numbers. The AF&PA data for 2000 shown in Table 3.4 reports self generated at 57.2%, which compares closely to the MECS "Other" of 54.3%.

Table 3.4
AF&PA 2002 Statistics
Estimated Fuel and Energy Used

Source	Estimated Fuel Used - 2000	
	TBtu	%
Purchased Electricity	155	7.1
Purchased Steam	34	1.6
Coal	266	12.2
No. 2 Oil	93	4.3
No. 6 Oil	9	0.4
Natural Gas	396	18.2
LPG	1	0.1
Other Purchased	23	1.0
Energy Sold		
Total Purchased	**932**	**42.8**
Hog	327	15.0
Black Liquor	895	41.1
Hydro Power	5	0.2
Other	20	0.9
Self Generated	**1,247**	**57.2**
Total Energy	**2,179**	**100.0**

Paper Industry Production

AF&PA 2004 Statistics reported the revised production data for the year 2002 as shown in Figures 3.1 and 3.2 and Tables 3.5 and 3.6. These data are the basis for the production figures used in the current bandwidth study. Note that all tonnage units in this report are short tons unless otherwise indicated. The AF&PA production figures were compared against Fisher International's database[5]. The check did not show any significant differences. From Table 3.6 it can be seen that kraft pulp accounts for 57% of the total pulp production (total virgin pulp is 66.8% of the total) in the U.S. and recycled OCC accounts for 19.3% of total pulp and over half of the recycled pulp (all recycle is 33.0% of the total pulp).

The data summarized in the tables shown above become the basis, energy consumption and industry production, for the bandwidth study.

Figure 3.1

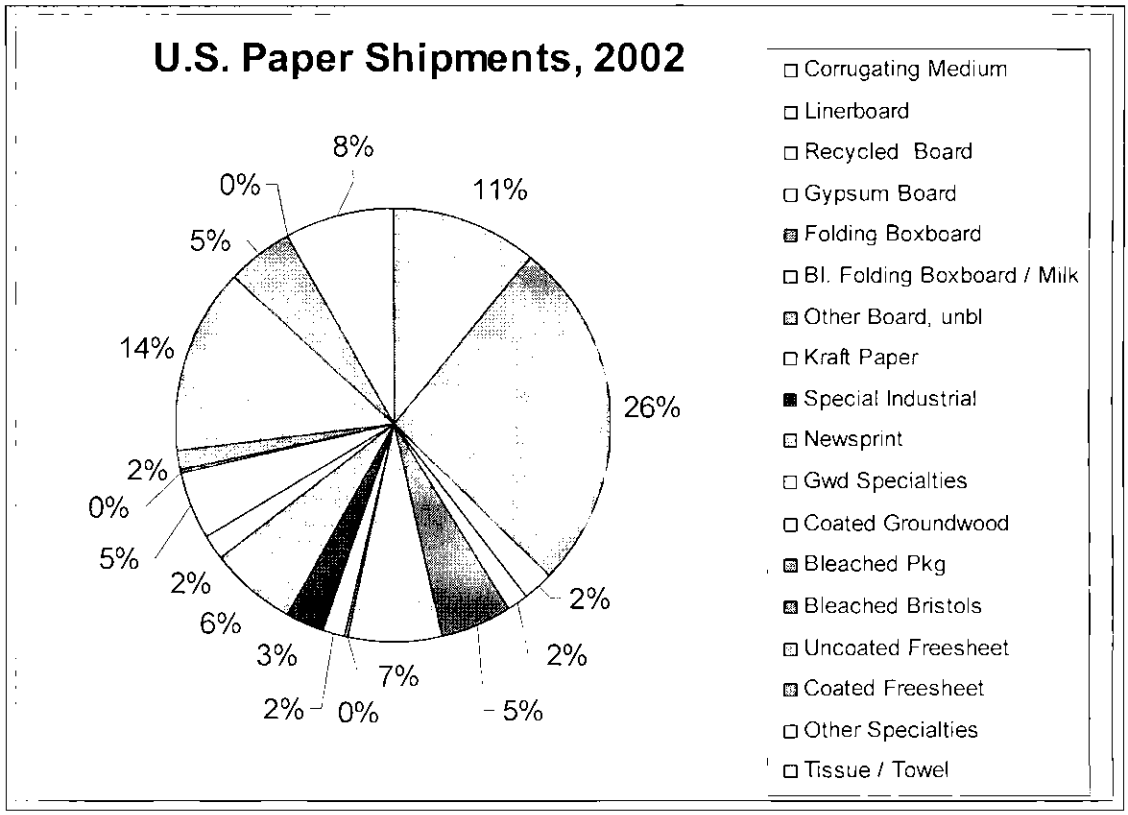


Table 3.5

AF&PA 2004 Statistics
2002 Shipments

Paper Product	(1,000 tons)	% of Total
Corrugating Medium	9,806	9.9
Linerboard	23,509	23.6
Recycled Board	2,062	2.1
Gypsum Board	1,429	1.4
Folding Boxboard	4,729	4.8
Bleached Folding Boxboard / Milk	6,346	6.4
Other Board, unbleached	247	0.2
Kraft paper	1,545	1.6
Special Industrial	2,323	2.3
Newsprint	5,784	5.8
Groundwood Specialties	1,668	1.7
Coated Groundwood	4,481	4.5
Bleached Packaging	291	0.3
Bleached Bristol	1,350	1.4
Uncoated Freesheet	12,428	12.5
Coated Freesheet	4,481	4.5
Other Specialties	83	0.1
Tissue & Towel	7,127	7.2
Subtotal	**89,687**	**90.1**
Kraft Pulp, bleached	8,153	8.2
Kraft Pulp, unbleached	na	na
Sulfite Pulp	na	na
Recycled Pulp	na	na
Other Pulp / Dissolving Pulp	1,705	1.7
Subtotal	**9,858**	**9.9**
Total	**99,545**	**100.0**

Figure 3.2

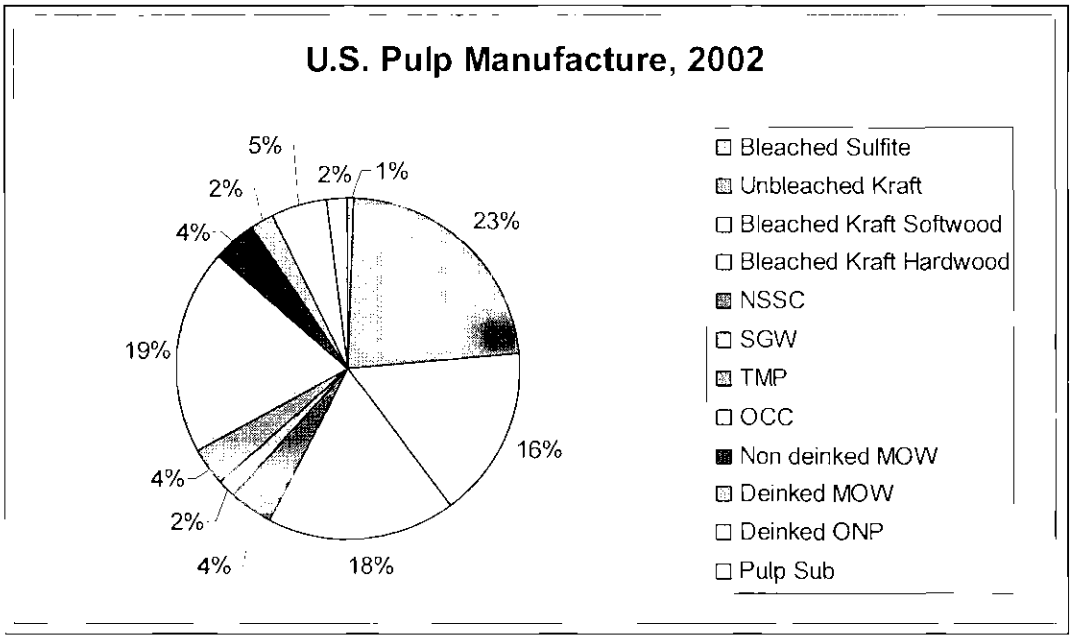


Table 3.6

AF&PA 2004 Statistics
2002 Pulp Production

Type	(1,000 tons)	% of Total
Bleached Sulfite	532	0.6
Unbleached Kraft	19,917	23.0
Bleached Kraft Softwood	13,848	16.0
Bleached Kraft Hardwood	15,404	17.8
NSSC	3,547	4.1
SWG	1,416	1.6
TMP	3,264	3.8
OCC	16,683	19.3
Non Deinked MOW	3,658	4.2
Deinked MOW	2,021	2.3
Deinked ONP	4,442	5.1
Pulp Substitutes	1,705	2.0
Total	**86,437**	**100.0**

4. PAPER INDUSTRY AVERAGE PROCESS ENERGY DEMAND

Average Energy Demand in Pulping and Papermaking

This study is production weighted, i.e., the energy consumed is based on the tons of pulp and paper produced by type (kraft, TMP, printing & writing, linerboard, etc.) multiplied by the energy consumed by ton for the various large process areas within a mill. Examples of large process areas are: pulping, bleaching, liquor evaporation, stock preparation, paper drying, etc. As such, even though TMP consumes a large quantity of electric power per unit of pulp produced, since only a small quantity of TMP pulp is produced in the U.S., total energy consumed is small compared to the energy consumed by U.S. pulp and paper industry. This report focuses on the large blocks of energy consumed by the U.S. pulp and paper industry rather than the large process units with relatively little impact on the industry's total energy consumption.

To establish a relationship between the MECS energy numbers and the AF&PA production (shipment) Jacobs and IPST/GT used as a starting point consumption figures, as units per ton, available from databases that Jacobs and IPST/GT had access to and information that had been published.

Comparison of the various databases shows that there are wide variations in the reported amount of energy used by different pulping processes and by the individual process steps. The same goes for the paper manufacturing energy information. The large differences between the databases and the published information are in part due to the large number of manufacturing variables, including age of equipment, mill / system configuration, and mill reporting systems (e.g., not all mills have the same accounting systems or mill system classifications; metering systems are in many cases missing; data is in some cases assumed based on other mill operations, leading to potentially incorrect results). Thus, using an average number based on the various databases minimizes the impact of the use of incorrect information.

The first step was to determine how much of the fuel consumed by the Paper Industry was actually available for manufacturing processes, i.e., we had to determine how much fuel was consumed in the powerhouse based on boiler efficiencies and energy estimates for auxiliary systems (fans, pumps, coal crushers, bark hog, turbine loses, transformer losses, environmental systems, etc.) and other losses such as leaks and venting. Based on a simple analysis, it was estimated that approximately 68% of the 2,361 Trillion Btu (TBtu) reported in MECS Table 3.2 is available for paper industry manufacturing processes, or 1,606 TBtu (Table 4.1).

The second step was to distribute the energy consumed in the pulp and paper making processes. We utilized published data that referenced energy consumption per ton. The references show a wide range of energy consumption for the same unit operation and/or paper grade. We made an initial estimate based on consumption numbers obtained from Paprican's book "Energy Cost Reduction in the Pulp and

Paper Industry" and AF&PA reported production numbers. The unit consumption figures were adjusted so the total energy consumption matched the energy available for process after the powerhouse.

The next step was to distribute the energy into smaller energy process blocks. We utilized the available published data and adjusted the data based on our knowledge of the industry. To minimize errors, we elected to use as large a database of published information as we could find to generate an average since the published data for the same processes vary.

References used to establish the basis for unit consumption per ton were:

- Energy Cost Reduction in the Pulp and Paper Industry, a Monograph[6];
- Energy Cost Reduction in Pulp & Paper Industry - An Energy Benchmarking Perspective[7],
- Pulp & Paper Industry, "Energy Best Practices,"[8]
- IPST's benchmarking model[9]
- White Paper No.10 Environmental Comparison – Manufacturing Technologies[10]
- Energy and Environmental Profile of the U.S. Forest Products Industry Volume 1: Paper Manufacture[11],
- A Guide to Energy Savings Opportunities in the Kraft Pulp Industry[12],
- Energy Efficiency and the Pulp and Paper Industry, Report IE962[13];
- The Energy Roadmap – Pulp and Paper for a Self-Sufficient Tomorrow[14],
- Benchmarking Energy Use in Pulp and Paper Operations[15]

The energy use within the U.S. Pulp and Paper Industry manufacturing pulp and paper products is broken down into three use categories: Electric, Steam and Direct Fuel. Figure 4.1 shows the distribution. Figures 4.2 and 4.4 show the distribution on total energy (electric, seam and direct fuel) for pulping and for paper manufacturing by product, respectively. Kraft pulping, bleached and unbleached, accounts for 78% of the total energy consumed by pulping. Pulp mill energy use by type and papermaking energy use by grade are provided in Figures 4.3 and 4.5. Energy distribution within manufacturing is shown in Table 4.2.

Table 4.1
Powerhouse Energy Consumption

	MECS 2002 Table 3.2 NAICS 322	Fuel Utilized In Boilers	Boiler Efficiency	Net Energy	Used for Soot Blowing Steam	Used for Boiler Aux.	Net Energy	Percent of Energy Used to Generate Electricity	Electrical Generation Conversion Loss	System & Mechanical Loss	Total Available for Process	Electricity	Electricity	Direct Fuel	Steam	% of Feed Available for Process
	TBtu	%	%	TBtu	%	%	TBtu	%	%	%	TBtu	TBtu	BkWh	TBtu	TBtu	%
Purchased Electricity	223	0%	98%	223	0%	0%	223	0%	9%	2%	218.5	218.5	64.1			98%
Coal	234	100%	86%	201	2.5%	6.0%	184	19.3%	9%	6%	170.1	30.4	8.9	-	139.7	73%
Residual Fuel Oil	100	100%	86%	86	0%	4.0%	83	19.3%	9%	6%	76.3	13.6	4.0	-	62.6	76%
Distillate Fuel Oil	13	70%	86%	12	0%	3.0%	11	0.0%	9%	6%	10.7	-	-	3.2	7.5	82%
Natural Gas	504	70%	87%	458	0%	3.0%	444	4.9%	9%	6%	415.9	18.4	5.4	119.2	278.2	83%
LPG	6	0%	87%	6	0%	0.0%	6	0.0%	9%	0%	6.0	-	-	6.0	-	100%
Waste Pulping Liquors	820	100%	64%	525	7.5%	4.0%	464	19.3%	9%	6%	429.0	76.6	22.4	-	352.4	52%
Wood / Bark	316	100%	69%	218	1.5%	5.0%	204	19.3%	9%	6%	188.3	33.6	9.9	-	154.7	60%
Other By Products	22	80%	69%	17	0%	4.0%	16	0.0%	9%	6%	14.9	-	-	3.0	11.9	68%
Other	123	100%	69%	85	0%	4.0%	81	3.0%	9%	6%	76.4	2.1	0.6	-	74.3	62%
Subtotal - Fuels	2,138			1,607			1,494				1,388	174.7	51.2	131.4	1,081.4	65%
Total	**2,361**			**1,830**			**1,717**				**1,606.10**	**393.27**	**115.26**	**131.43**	**1,081.40**	**68%**

Boiler Efficiencies: conversion efficiency of the boiler, based on Jacobs' design rule of thumb.

Soot Blowing Steam: steam used in the boiler for tube cleaning, based on Jacobs' design rule of thumb.

Boiler Auxiliaries: include energy consumed for fans, pumps, coal crushers, bark hogs, environmental controls, steam leaks and venting, etc.

Electrical Generator Conversion Loss: energy / heat loss in the generator and condenser.

System and Mechanical Loss: energy / heat loss in transformers, radiation losses form pipes, venting and leaks.

Electricity generated on-site is 51.21 BkWh (44% of the total 115 BkWh) electricity used by the processes.

Total fuel consumed by the industry is 2,138 TBtu of which 1,388 TBtu (65% of the feed) is available for use in the pulp and paper manufacturing processes after the powerhouse (including 131 TBtu of fuel used directly as fuel in the process). The 2,007 TBtu difference between 2,138 TBtu and 131 TBtu is the fuel consumed in the powerhouse to co-generate the 1,256 TBtu of process steam and electricity.

Figure 4.1

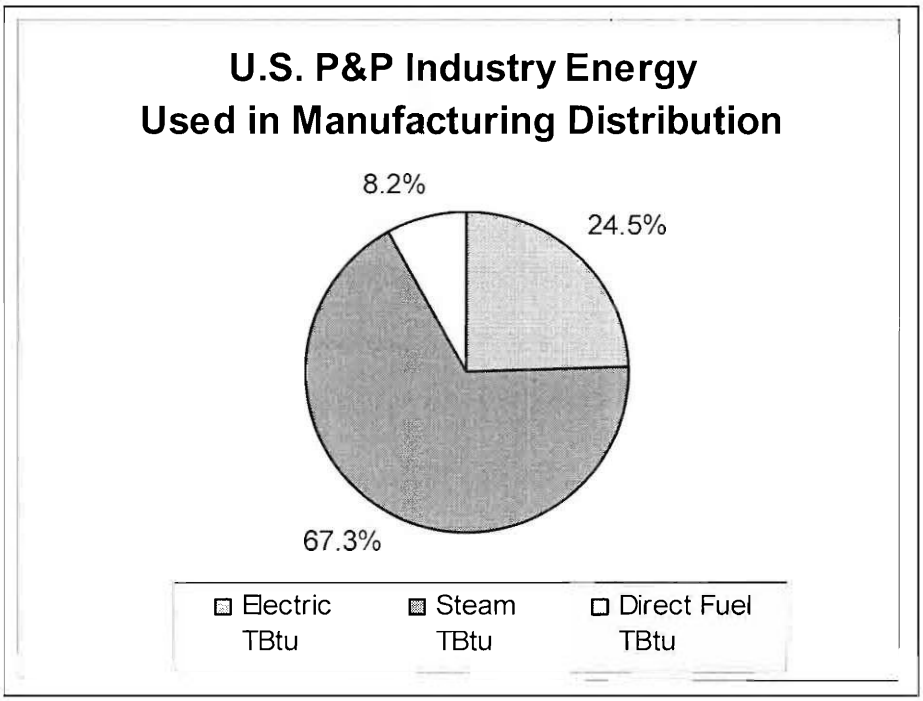


Figure 4.2

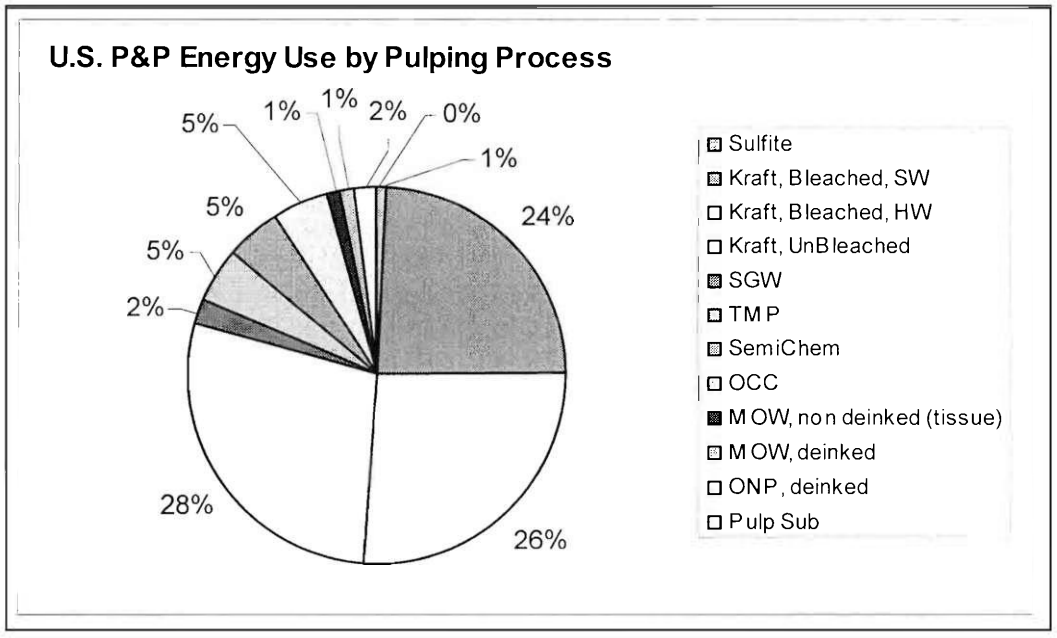


Figure 4.3

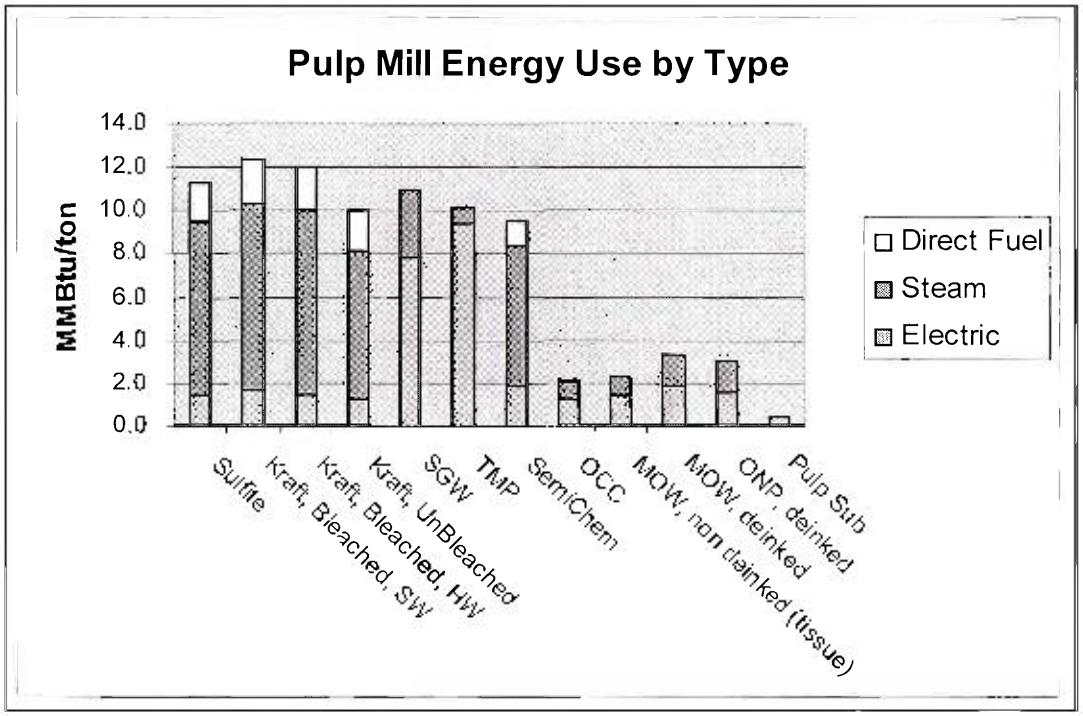


Figure 4.4

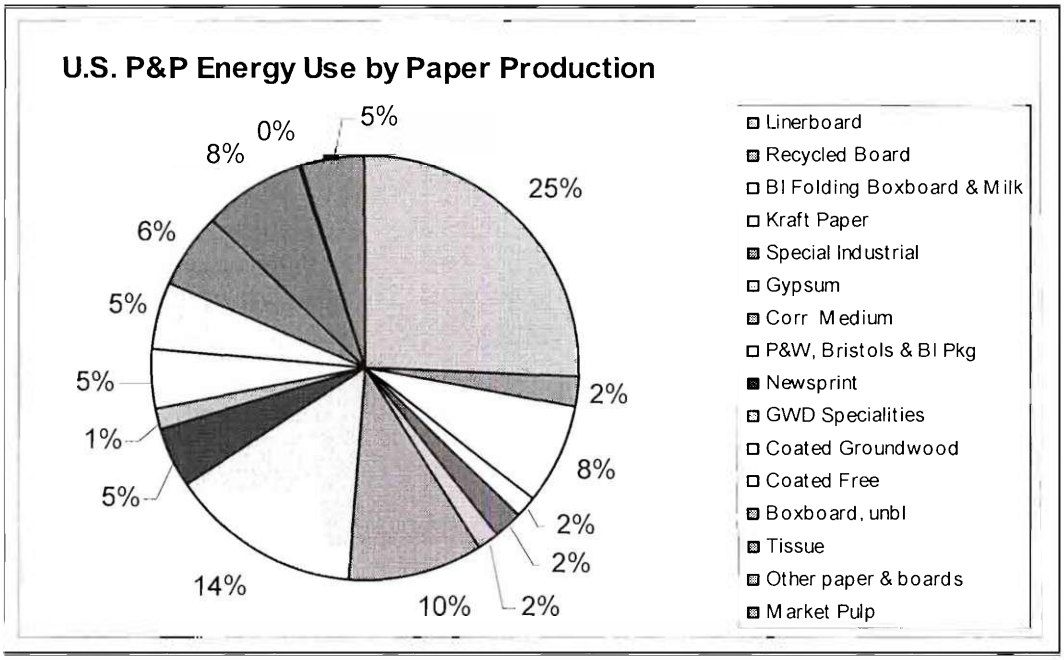


Figure 4.5

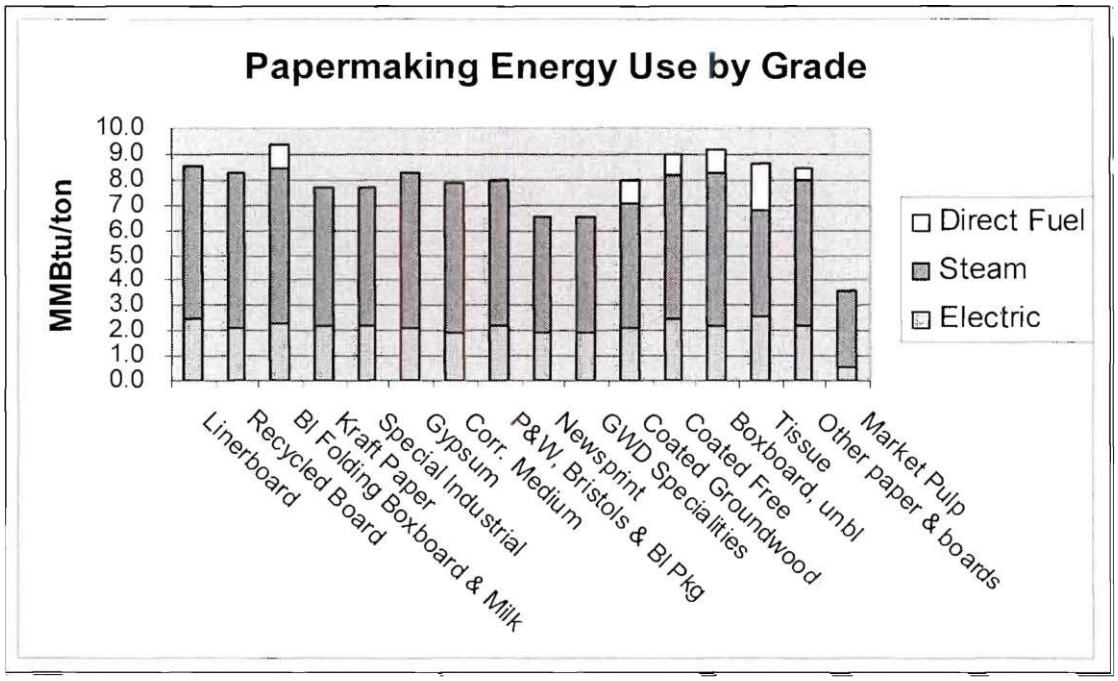


Table 4.2
U.S. P&P Energy Distribution

	Electric		Steam		Direct Fuel	
	TBtu	**%**	**TBtu**	**%**	**TBtu**	**%**
Pulp Manufacture	158.6	40.3	449.3	41.5	100.2	76.2
Paper Manufacture	206.9	52.6	537.8	49.7	31.3	23.8
Utilities, excluding Powerhouse	27.8	7.1	94.3	8.7	0.0	0
Total Manufacturing	**393.3** (24.5%)	100.0	**1,081.4** (67.3%)	100.0	**131.4** (8.2%)	100.0
Grand Total	**1,606.1** (100.0%)					

Steam and Electrical Energy Use by Process Area

Overall average break-downs of the energy used within pulp and paper manufacturing are shown in Table 4.3 and 4.4, respectively.

Table 4.3
Energy Used within Pulp Manufacturing

	Electrical Energy		Steam Energy		Direct Fuel Energy	
	TBtu	**%[d]**	**TBtu**	**%[d]**	**TBtu**	**%[d]**
Wood Preparation	17.8	11.2	14.4	3.2	0.0	0.0
Cooking[a]	18.9	11.9	130.1	29.0	0.0	0.0
Grinding / Refining[b]	36.8	23.2	-3.0	-0.7	0.0	0.0
Screening / Cleaning[c]	13.1	8.3	0.0	0.0	0.0	0.0
Evaporation	8.7	5.5	186.0	41.4	0.0	0.0
Chemical Preparation	9.4	6.0	30.3	6.7	100.2	100.0
Bleaching	15.6	9.9	64.8	14.4	0.0	0.0
Recycle / Pulp Subs	38.2	24.1	26.7	5.9	0.0	0.0
Total	**158.6** (22.4%)	100.0	**449.2** (63.5%)	100.0	**102.2** (14.1%)	100.0
Grand Total	**707.9** (100.0%)					

a. For chemical pulps includes digesting through washing
b. Includes heat recovery for TMP refiners
c. Screening & cleaning for mechanical pulping, energy for screening & cleaning of chemical pulp is in the cooking numbers
d. The percentages above represent an overall average for all pulping processes and vary for individual processes (e.g., kraft, NSSC, etc.)

Table 4.4
Energy Used within Paper Manufacturing

	Electrical Energy		Steam Energy		Direct Fuel Energy	
	TBtu	**%[c]**	**TBtu**	**%[c]**	**TBtu**	**%[c]**
Wet End[a]	103.2	49.9	107.8	20.0	0.0	0.0
Pressing	36.5	17.7	0.0	0.0	0.0	0.0
Drying	45.0	21.7	422.3	78.5	13.4	42.7
Dry End[b]	18.4	8.9	0.0	0.0	0.0	0.0
Coating Preparation	1.2	0.6	2.5	0.5	0.0	0.0
Coating Drying	0.0	0.0	0.0	0.0	17.9	57.3
Super Calendering	2.7	1.3	5.3	1.0	0.0	0.0
Total	**206.9** (26.7%)	100.0	**542.3** (69.3%)	100.0	**31.3** (4.0%)	100.0
Grand Total	**776.0** (100.0%)					

a. Wet End includes stock preparation through forming
b. Dry End includes calendering through winding
c. The percentages above represent an overall average for all papermaking processes and vary for individual processes (e.g., liner, uncoated freesheet, tissue, etc.)

Direct Fuel

In the area of pulp manufacturing 100% of the direct fuel is used in either the lime kilns (Kraft pulping – 99.3%) or sulfur burners (sulfite pulping – 0.7%).

In the area of paper manufacturing 100% of the direct fuel is used either for coating drying (57%) and/or in tissue drying (Yankee hoods and/or Through Air Drying (TAD) – 43%).

Summary

Using the electrical, steam and direct fuel energy consumption data by pulping and paper grade, along with production data (Tables 3.5 and 3.6), total domestic energy consumption was obtained (Table 4.5). Figures 4.6, 4.7 and 4.8 graphically displays the energy consumption of a bleached hardwood kraft mill along with a printing and writing paper machine, unbleached kraft with linerboard machine and TMP with a Newsprint machine, respectively. The three combinations are shown to represent differences between pulping and paper machine combinations, however, pulping is not truly representative since most machines blend various pulps together rather than use just a single type, i.e. pulp for linerboard can be either 100% unbleached kraft, 100% OCC, or varying ratios of the two. The same is true for Printing & Writing (mixtures of bleached hardwood, bleached softwood and MOW) and Newsprint (mixtures of TMP, stone groundwood, kraft and ONP). Figures 4.9 and 4.10 show the distribution of energy consumption by major mill process area.

Table 4.5
Energy Distribution Overview

	Elec kWh/t	Elec MMBtu/t	Steam MMBtu/t	Direct Fuel MMBtu/t	Production 1000 t/yr	Production %	Elec Million kWh	Electric TBtu	Steam TBtu	Direct Fuel TBtu	Total TBtu
Sulfite	434.3	1.5	8.00	1.78	532	0.6%	231	0.8	4.3	0.9	6.0
Kraft, Bleached, SW	484.0	1.7	8.74	1.97	13,848	16.0%	6,702	22.9	121.0	27.3	171.2
Kraft, Bleached, HW	434.3	1.5	8.53	1.97	15,404	17.8%	6,690	22.8	131.4	30.4	184.6
Kraft, UnBleached	372.3	1.3	6.84	1.87	19,917	23.0%	7,415	25.3	136.3	37.3	198.9
SGW	2,283.3	7.8	3.16		1,416	1.6%	3,233	11.0	4.5	0.0	15.5
TMP	2,761.1	9.4	0.74		3,264	3.8%	9,012	30.7	2.4	0.0	33.2
SemiChem	564.6	1.9	6.42	1.17	3,547	4.1%	2,003	6.8	22.8	4.2	33.8
OCC	372.3	1.3	0.84		16,683	19.3%	6,211	21.2	14.1	0.0	35.2
MOW, non deinked (tissue)	434.3	1.5	0.84		3,658	4.2%	1,589	5.4	3.1	0.0	8.5
MOW, deinked	558.4	1.9	1.47		2,021	2.3%	1,129	3.9	3.0	0.0	6.8
ONP, deinked	465.3	1.6	1.47		4,442	5.1%	2,067	7.1	6.5	0.0	13.6
Pulp Sub	111.7	0.4			1,705	2.0%	190	0.6	0.0	0.0	0.6
Sub Total					**86,437**	**100.0%**	**46,472**	**158.6**	**449.3**	**100.2**	**708.0**
Linerboard	713.5	2.4	6.11		23,509	23.6%	16,774	57.2	143.6	0.0	200.8
Recycled Board	620.5	2.1	6.11		2,061	2.1%	1,279	4.4	12.6	0.0	17.0
BI Folding Boxboard & Milk	682.5	2.3	6.11	0.89	6,346	6.4%	4,331	14.8	38.7	5.6	59.2
Kraft Paper	651.5	2.2	5.47		1,545	1.6%	1,006	3.4	8.5	0.0	11.9
Special Industrial	651.5	2.2	5.47		2,323	2.3%	1,514	5.2	12.7	0.0	17.9
Gypsum	620.5	2.1	6.11		1,429	1.4%	886	3.0	8.7	0.0	11.7
Corr. Medium	558.4	1.9	6.00		9,806	9.9%	5,476	18.7	58.8	0.0	77.5
P&W, Bristols & BI Pkg	645.3	2.2	5.75		14,069	14.1%	9,078	31.0	80.9	0.0	111.9
Newsprint	558.4	1.9	4.63		5,784	5.8%	3,230	11.0	26.8	0.0	37.8
GWD Specialities	558.4	1.9	4.63		1,668	1.7%	931	3.2	7.7	0.0	10.9
Coated Groundwood	620.5	2.1	4.95	0.89	4,481	4.5%	2,780	9.5	22.2	4.0	35.6
Coated Free	719.7	2.5	5.69	0.89	4,481	4.5%	3,225	11.0	25.5	4.0	40.5
Boxboard, unbl	639.1	2.2	6.11	0.89	4,729	4.8%	3,022	10.3	28.9	4.2	43.4
Tissue	744.6	2.5	4.21	1.87	7,127	7.2%	5,307	18.1	30.0	13.4	61.5
Other paper & boards	651.5	2.2	5.79	0.39	330	0.3%	215	0.7	1.9	0.1	2.8
Market Pulp	160.3	0.5	3.07		9,858	9.9%	1,581	5.4	30.3	0.0	35.7
Sub Total					**99,545**	**100.0%**	**60,636**	**206.9**	**537.8**	**31.3**	**776.0**
Wastewater & Utilities	81.9	0.3	0.95		99,545		8,153	27.8	94.3	0.0	122.1
Grand Total							**115,260**	**393.3**	**1,081.4**	**131.4**	**1,606.1**

Figure 4.6
Average Bleached Hardwood Kraft Pulp and Printing and Writing Paper

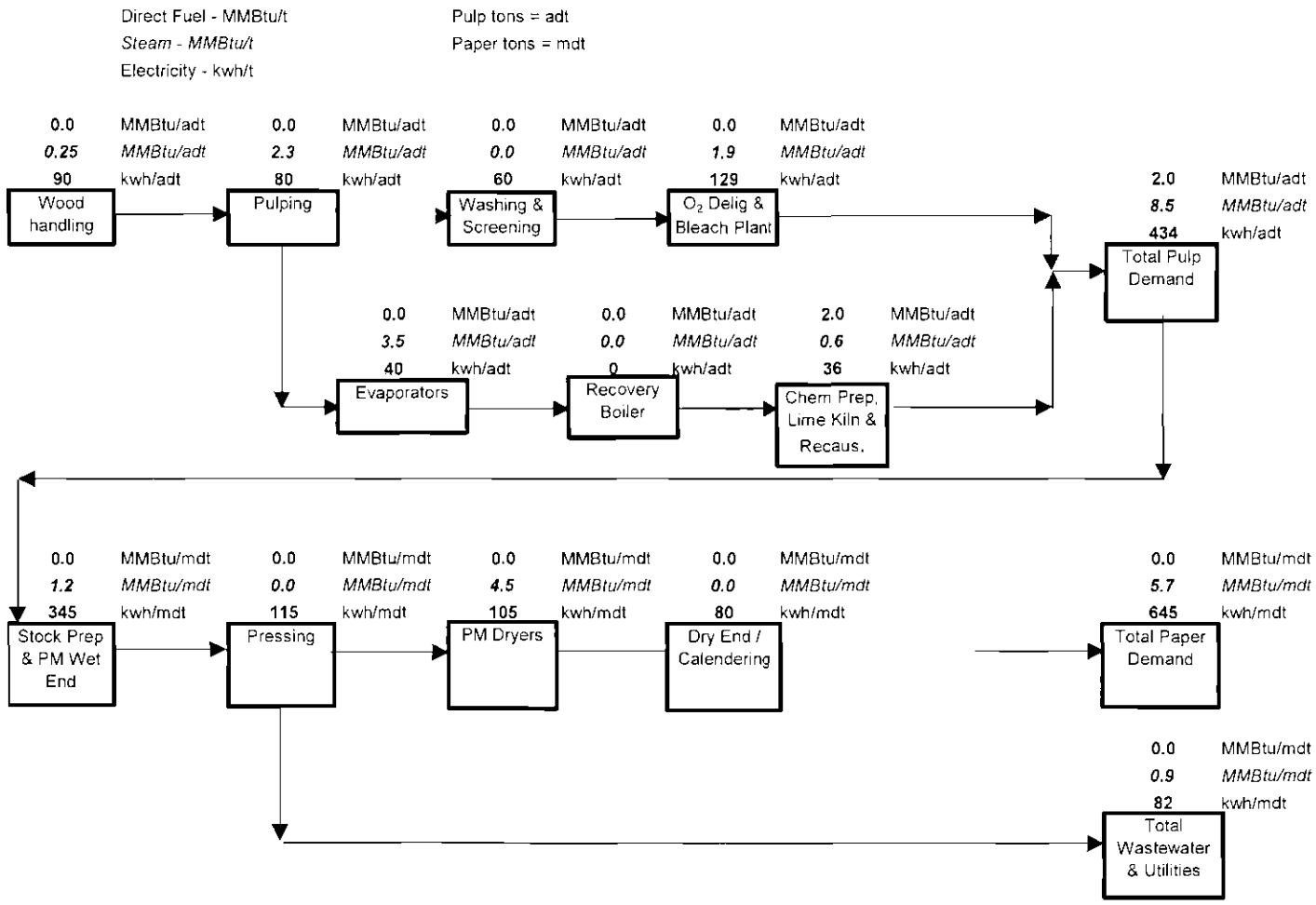


Figure 4.7
Average Unbleached Kraft Pulp and Linerboard

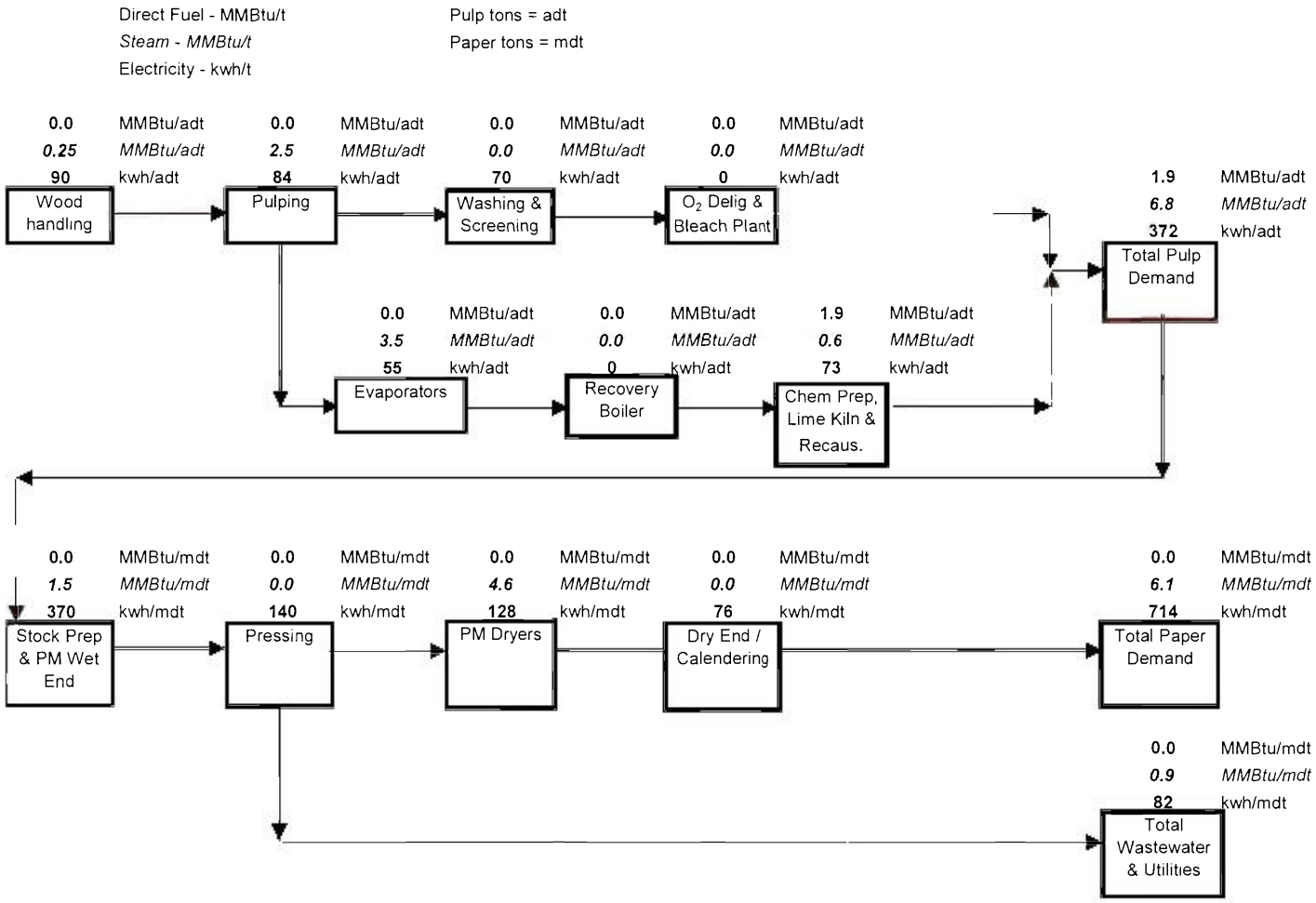


Figure 4.8
Average TMP and Newsprint

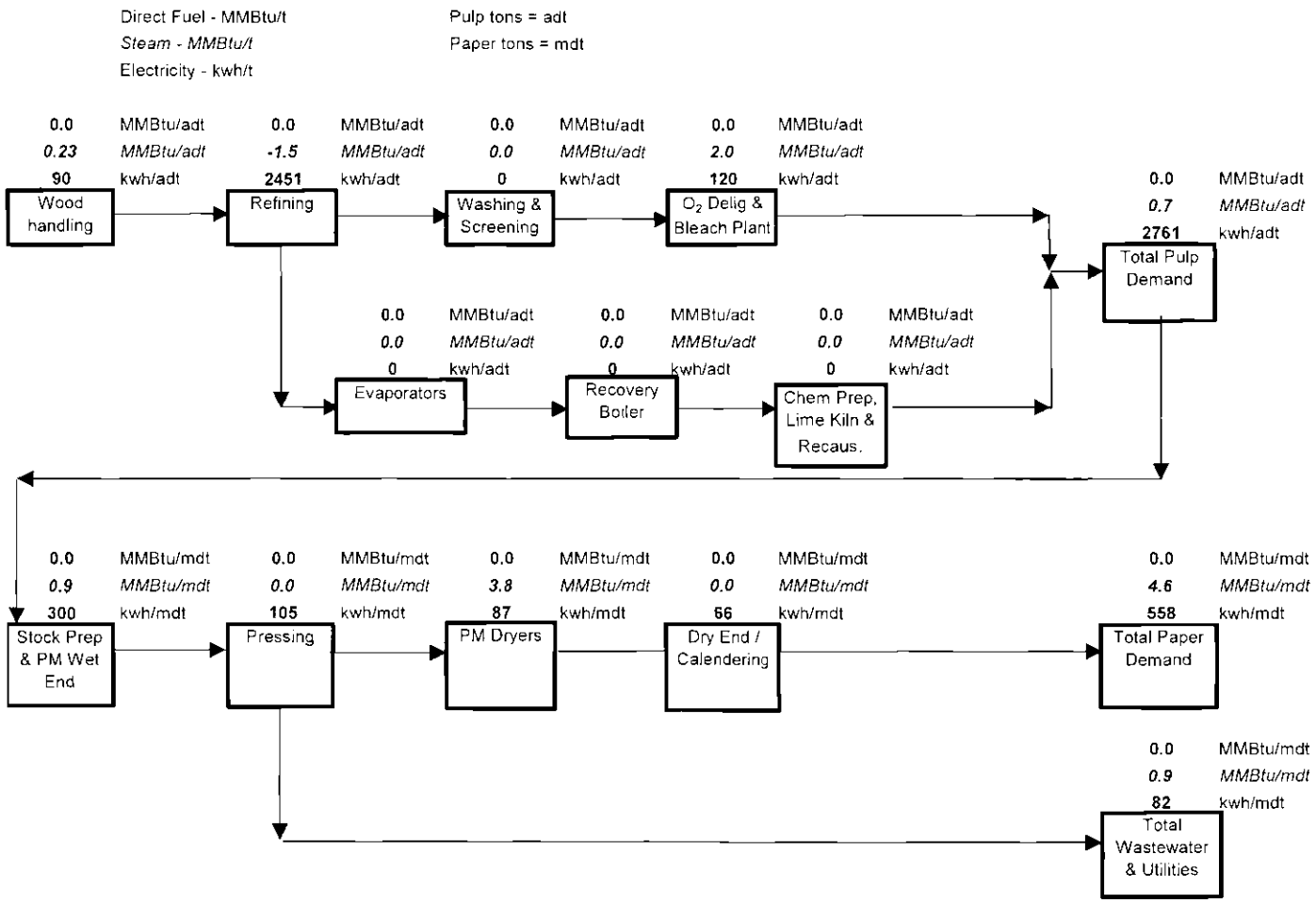


Figure 4.9

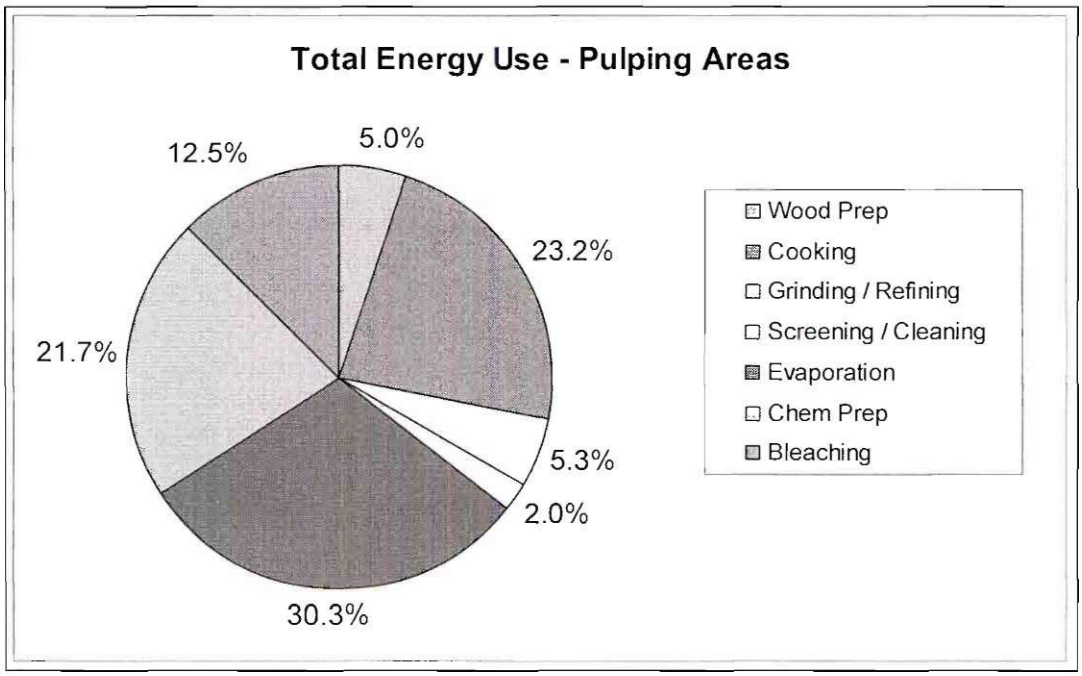
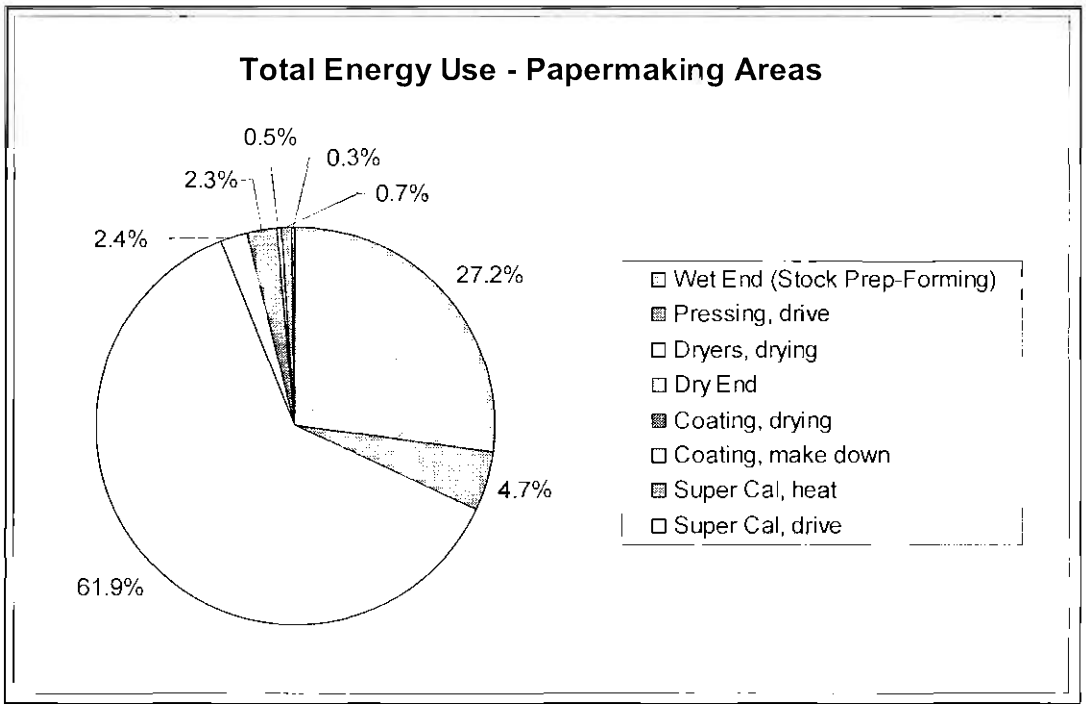


Figure 4.10



5. OVERALL DOMESTIC ENERGY BALANCE

Combination of the consumption data (Table 4.5) and the generation data (Table 4.1) allows the overall domestic energy balance to be calculated (Table 5.1). There is good agreement between the net mill demand and the MECS Industry Demand (Table 5.1).

Table 5.1

COMPARISON OF TOTAL MILL NET FUEL DEMAND VERSUS MECS							
	Basis MMton/yr	Electric Energy kWh/ton	Steam Energy MMBtu/ton	Direct Fuel MMBtu/ton	Total Electric MMkWh	Total Steam TBtu	Direct Fuel TBtu
Total Pulping Process Demand	86.44	537.64	5.20	1 16	46,472	449.26	100.16
Total Papermaking Demand	99.55	609.13	5.40	0.31	60,636	537.81	31.28
Wastewater Treatment					8,153	94.33	0
Total Industry Proc. Demand	**99.55**	**1157.82**	**10.86**	**1.32**	**115,261**	**1,081.4**	**131.4**
Total Boilers Gross (Gen)	99.55				(51,210)	(1081.4)	2007.0
Power Plant Demand	99.55				1,307		
Net Total Boilers Demand	**99.55**				**(49,903)**	**(1,081)**	**2,007**
Total Mill Demand w/Direct					**65,358**	**0**	**2,138.4**
MECS Industry Demand					**65,358**	**0.0**	**2,138.0**

The 4.5 TBtu (223 TBtu – 218.5 TBtu) difference in purchase electricity, due to 2% system loses, shown in Table 4.1, is equivalent to the 1,307 Million kWh shown above as powerhouse demand.

6. ESTIMATED CONSUMPTION WITH "BAT"

The estimated energy consumption using BAT was obtained by using the MECS / AF&PA production data as a basis and then using published data for either modern and/or model mills. We elected to use published information because modern design data related to new mills is limited; the last new, greenfield pulp mill built in the U.S. occurred in the early 1980's. (Recent construction of new mills has occurred in Asia and South America.) In some cases, such as sulfite pulping, there isn't any data that represents a current mill design since the pulping technology, for the most part, is being phased out. In cases like sulfite, the energy data used for the MECS distribution is reused.

The methodology that was used in the MECS distribution remains the same, (using the electrical, steam and direct fuel energy consumption data by pulping and paper grade, along with production data (Tables 3.5 and 3.6)), except that the BAT distribution is used to predict fuel use by back calculating through the powerhouse i.e., Table 6.1 was generated, and then Table 6.2 was back calculated. The efficiencies used in the powerhouse are the best rather than the average. Since pulp production has been maintained, the amount of energy available from hog fuel and black liquor has been maintained (Table 4.1) causing other quantities available from other energy sources to float.

The analysis showed that by using current design technology overall energy used in the papermaking and pulping processes could be reduced by 28.0%, from 1,606 TBtu to 1,157 TBtu. Tables 6.1 and 6.3 summarize the changes. Figures 6.1 through 6.4 show the energy distribution and use within the pulp and papermaking processes after applying BAT. Applying BAT reduces purchased fuels, excluding electricity, to 458 TBtu (Table 6.2). BAT is a combination of application of new technologies, such as shoe presses, and the improved utilization of energy by capturing and reusing energy contained in "waste" process streams, such as paper machine dryer hoods and bleach plant effluents. Figures 6.5 and 6.6 show the distribution of energy consumption by major mill process areas.

References used to establish the basis for unit consumptions were:

- Energy Cost Reduction in Pulp & Paper Industry - An Energy Benchmarking Perspective[16],
- Pulp & Paper Industry, "Energy Best Practices,"[17]
- A Guide to Energy Savings Opportunities in the Kraft Pulp Industry[18],
- Energy Efficiency and the Pulp and Paper Industry, Report IE962[19];
- Energy Cost Reduction in the Pulp and Paper Industry, a Monograph[20]

Table 6.1
BAT Energy Distribution Overview

	Current Electric kWh/t	BAT Electric kWh/t	BAT Electric MMBtu/t	Electric % change	Current Steam MMBtu/t	BAT Steam MMBtu/t	Steam % change	Current Direct Fuel MMBtu/t	BAT Direct Fuel MMBtu/t	Direct Fuel % change	Production 1000 t/yr	Production %	Elec Million kWh	Electric TBtu	Steam TBtu	Direct Fuel TBtu	Total TBtu
Sulfite	434	406	1.4	-6.6%	8.0	7.64	-4.5%	1.8	1.8	-0.8%	532	0.6%	216	0.7	4.1	0.9	5.7
Kraft, Bleached, SW	484	363	1.2	-25.0%	8.7	6.34	-27.5%	2.0	1.4	-30.6%	13,848	16.0%	5,027	17.2	87.8	19.0	123.9
Kraft, Bleached, HW	434	347	1.2	-20.1%	8.5	5.58	-34.6%	2.0	1.3	-36.6%	15,404	17.8%	5,345	18.2	86.0	19.3	123.4
Kraft, UnBleached	372	269	0.9	-27.7%	6.8	4.66	-31.9%	1.9	1.5	-21.0%	19,917	23.0%	5,358	18.3	92.8	29.5	140.6
SGW	2283	2,133	7.3	-6.6%	3.2	3.00	-5.0%	0.0	0.0		1,416	1.6%	3,020	10.3	4.2	0.0	14.6
TMP	2761	2,088	7.1	-24.4%	0.7	0.58	-21.3%	0.0	0.0		3,264	3.8%	6,815	23.3	1.9	0.0	25.1
SemiChem	565	527	1.8	-6.6%	6.4	5.00	-22.1%	1.2	1.2	-2.0%	3,547	4.1%	1,871	6.4	17.7	4.1	28.2
OCC	372	206	0.7	-44.7%	0.8	0.60	-28.8%	0.0	0.0		16,683	19.3%	3,437	11.7	10.0	0.0	21.7
MOW, non deinked (tissue)	434	348	1.2	-19.9%	0.8	0.60	-28.8%	0.0	0.0		3,658	4.2%	1,273	4.3	2.2	0.0	6.5
MOW, deinked	558	472	1.6	-15.5%	1.5	1.33	-9.8%	0.0	0.0		2,021	2.3%	954	3.3	2.7	0.0	5.9
ONP, deinked	465	395	1.3	-15.1%	1.5	1.33	-9.8%	0.0	0.0		4,442	5.1%	1,755	6.0	5.9	0.0	11.9
Pulp Sub	112	104	0.4	-6.6%	0.0	0.00	0.0%	0.0	0.0		1,705	2.0%	178	0.6	0.0	0.0	0.6
Sub Total											**86,437**	**100.0%**	**35,248**	**120.3**	**315.3**	**72.7**	**508.3**
Linerboard	714	472	1.6	-33.9%	6.1	3.08	-49.6%	0.0	0.0		23,509	23.6%	11,096	37.9	72.4	0.0	110.3
Recycled Board	620	315	1.1	-49.2%	6.1	4.00	-34.5%	0.0	0.0		2,061	2.1%	649	2.2	8.2	0.0	10.5
BI Folding Boxboard & Milk	683	512	1.7	-25.0%	6.1	3.41	-44.2%	0.9	0.9	-0.9%	6,346	6.4%	3,249	11.1	21.6	5.6	38.3
Kraft Paper	651	472	1.6	-27.6%	5.5	3.08	-43.7%	0.0	0.0		1,545	1.6%	729	2.5	4.8	0.0	7.2
Special Industrial	651	472	1.6	-27.6%	5.5	3.08	-43.7%	0.0	0.0		2,323	2.3%	1,097	3.7	7.2	0.0	10.9
Gypsum	620	315	1.1	-49.2%	6.1	4.00	-34.5%	0.0	0.0		1,429	1.4%	450	1.5	5.7	0.0	7.3
Corr. Medium	558	472	1.6	-15.5%	6.0	3.08	-48.7%	0.0	0.0		9,806	9.9%	4,628	15.8	30.2	0.0	46.0
P&W, Bristols & BI Pkg	645	460	1.6	-28.7%	5.7	4.16	-27.6%	0.0	0.0		14,069	14.1%	6,472	22.1	58.5	0.0	80.6
Newsprint	558	328	1.1	-41.3%	4.6	3.32	-28.3%	0.0	0.0		5,784	5.8%	1,897	6.5	19.2	0.0	25.7
GWD Specialities	558	328	1.1	-41.3%	4.6	3.96	-14.5%	0.0	0.0		1,668	1.7%	547	1.9	6.6	0.0	8.5
Coated Groundwood	620	555	1.9	-10.6%	4.9	4.44	-10.3%	0.9	0.9	-0.9%	4,481	4.5%	2,487	8.5	19.9	3.9	32.3
Coated Free	720	500	1.7	-30.5%	5.7	3.83	-32.6%	0.9	0.9	-0.9%	4,481	4.5%	2,240	7.6	17.2	3.9	28.7
Boxboard, unbl	639	355	1.2	-44.5%	6.1	4.33	-29.1%	0.9	0.9	-0.9%	4,729	4.8%	1,679	5.7	20.5	4.2	30.4
Tissue	745	669	2.3	-10.1%	4.2	3.96	-6.0%	1.9	1.9	0.0%	7,127	7.2%	4,768	16.3	28.2	13.2	57.7
Other paper & boards	651	467	1.6	-28.3%	5.8	4.00	-30.9%	0.4	0.4	0.0%	330	0.3%	154	0.5	1.3	0.1	2.0
Market Pulp	160	160	0.5	-0.2%	3.1	2.53	-17.7%	0.0	0.0		9,858	9.9%	1,577	5.4	24.9	0.0	30.3
Sub Total											**99,545**	**100.0%**	**43,720**	**149.2**	**346.5**	**31.0**	**526.7**
Wastewater & Utilities	82	82	0.3	0.0%	0.9	0.95	0.0%	0.0	0.0		99,545		8,153	27.8	94.4	0.0	122.2
Grand Total													**87,120.5**	**297.26**	**756.14**	**103.73**	**1,157.1**
Current (MECS)													115,260.2	393.27	1,081.40	131.43	1,606.1
Difference, %													**-24.4%**	**-24.4%**	**-30.1%**	**-21.1%**	**-28.0%**

Table 6.2
Powerhouse Energy Consumption after BAT

	Estimate Based on BAT	Fuel Utilized In Boilers	Boiler Efficiency	Net Energy	Used for Soot Blowing Steam	Used for Boiler Aux.	Net Energy	Percent of Energy Used to Generate Electricity	Electrical Generation Conversion Loss	System & Mechanical Loss	Total Available for Process	Electricity	Electricity	Direct Fuel	Steam	% of Feed Available for Process
	TBtu	%	%	TBtu	%	%	TBtu	%	%	%	TBtu	TBtu	BkWh	TBtu	TBtu	%
Purchased Electricity	139	0%	98%	139	0%	0%	139	0%	9%	2%	135.8	135.8	39.8	-	-	98%
Coal	166	100%	88%	146	2.0%	6.0%	134	19%	9%	6%	123.8	23.5	6.9	-	100.3	75%
Residual Fuel Oil	60	100%	88%	53	0%	4.0%	51	19%	9%	6%	47.0	8.9	2.6	-	38.1	78%
Distillate Fuel Oil	9	70%	88%	8	0%	3.0%	8	0%	9%	6%	7.7	-	-	2.5	5.2	83%
Natural Gas	156	70%	89%	144	0%	3.0%	139	5%	9%	6%	130.4	3.0	0.9	94.1	33.3	84%
LPG	5	0%	88%	5	0%	0.0%	5	0%	9%	0%	4.7	-	-	4.7	-	100%
Waste Pulping Liquors	820	100%	68%	558	5.5%	4.0%	505	19%	9%	6%	465.9	88.4	25.9	-	377.5	57%
Wood / Bark	316	100%	70%	221	1.0%	5.0%	208	19%	9%	6%	192.1	36.4	10.7	-	155.6	61%
Other By Products	16	80%	70%	12	0%	4.0%	11	0%	9%	6%	10.7	-	-	2.4	8.3	67%
Other	62	100%	70%	43	0%	4.0%	42	3%	9%	6%	39.0	1.2	0.3	-	37.8	63%
Subtotal - Fuels	1,611			1,190			1,103				1,021	132.1	47.3	103.7	756.1	63%
Total	**1,749**			**1,329**			**1,242**				**1,157.1**	**297.3**	**87.1**	**103.7**	**756.1**	**66%**
2000 MECS	2,361			1,830			1,717				1,606	393.3	115.3	131.43	1081.4	
Difference, %	**-25.9%**			**-27.4%**			**-27.7%**				**-28.0%**	**-24.4%**	**-24.4%**	**-21.1%**	**-30.1%**	

Table 6.3
U.S. P&P Energy Distribution

	Electric			Steam			Direct Fuel		
	MECS TBtu	BAT TBtu	Diff. %	MECS TBtu	BAT TBtu	Diff. %	MECS TBtu	BAT TBtu	Diff. %
Pulp Manufacture	158.6	120.3	-24.2	449.2	315.3	-29.8	100.2	72.7	-27.4
Paper Manufacture	206.9	149.2	-27 9	537 8	346.5	-35.6	31.3	31 0	-1.0
Utilities, excluding Powerhouse	27.8	27.8	0.0	94.4	94.4	0.0	0.0	0.0	0.0
Total Manufacturing	**393.3**	**297.3**	**-24.4**	**1,081.4**	**756.1**	**-30.1**	**131.4**	**103.7**	**-21.1**

Figure 6.1

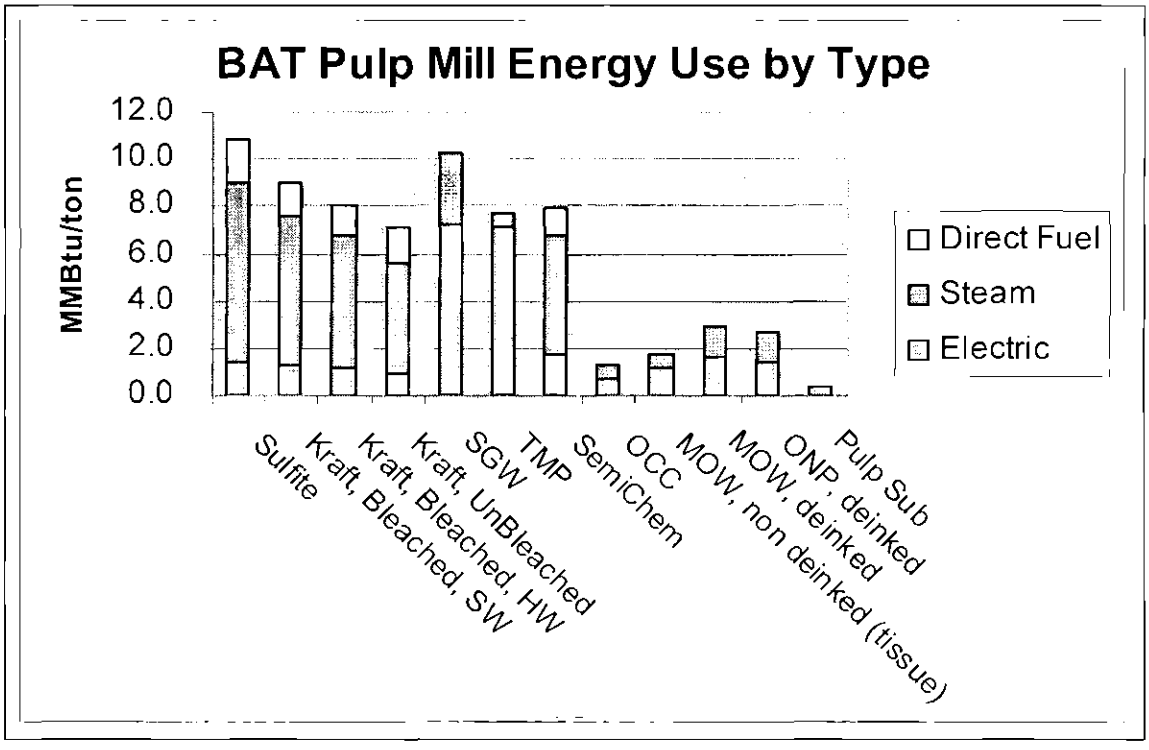


Figure 6.2

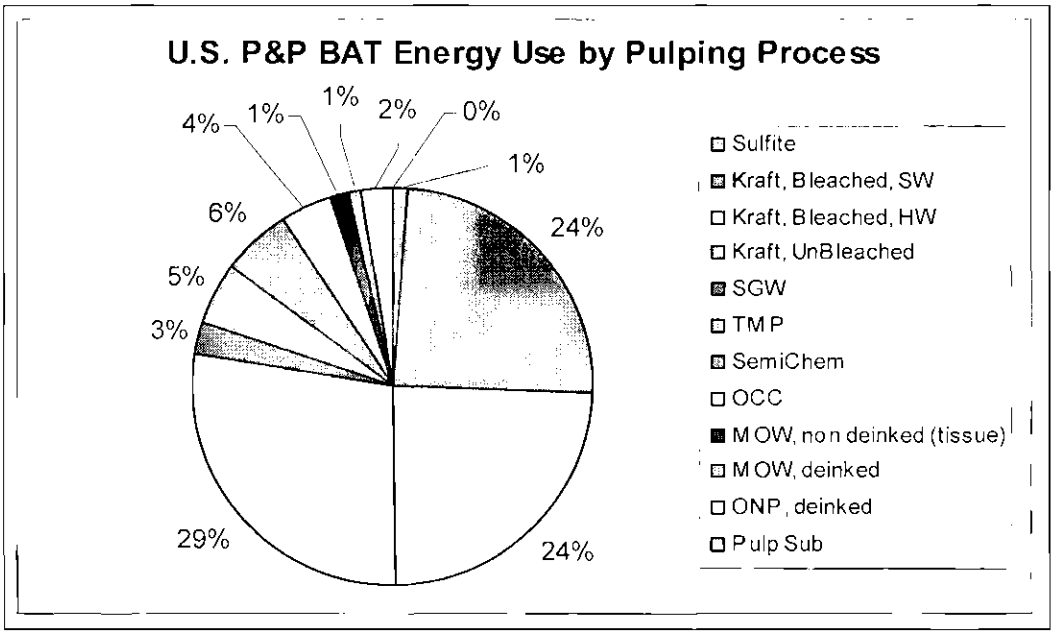


Figure 6.3

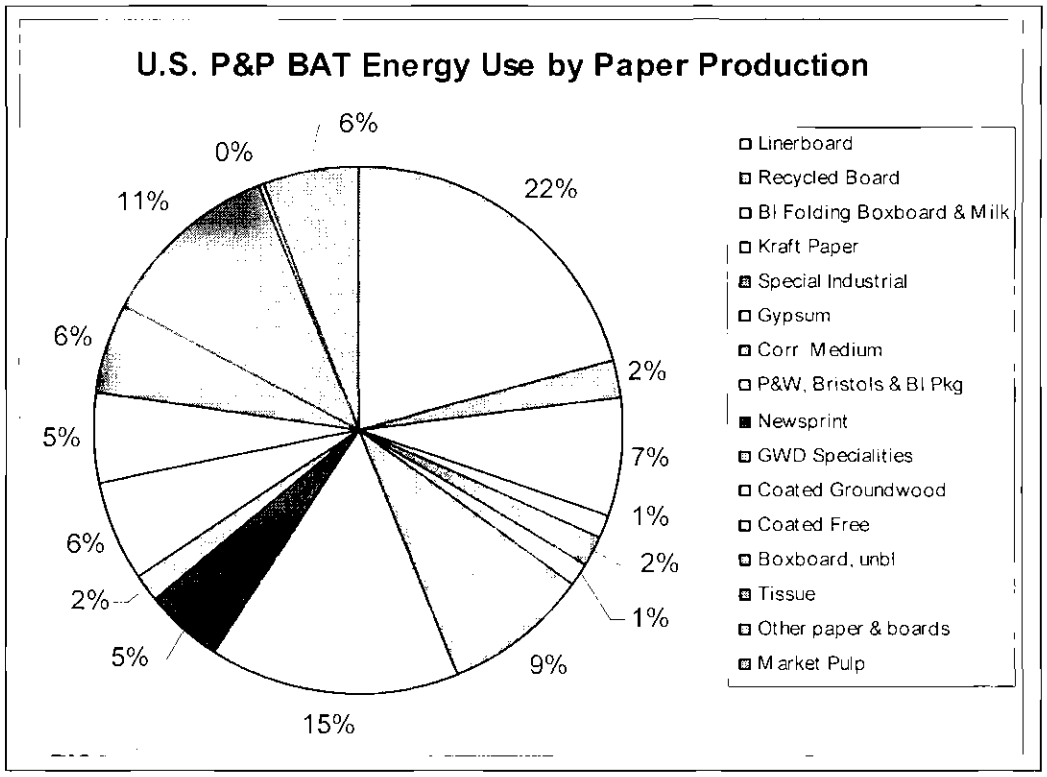


Figure 6.4

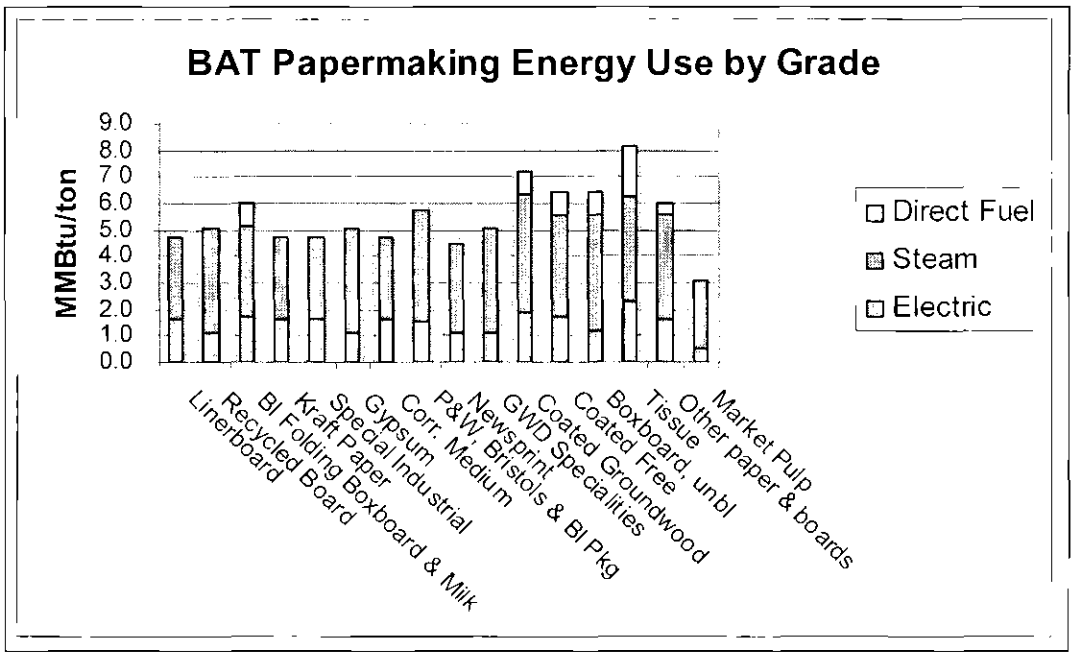


Figure 6.5

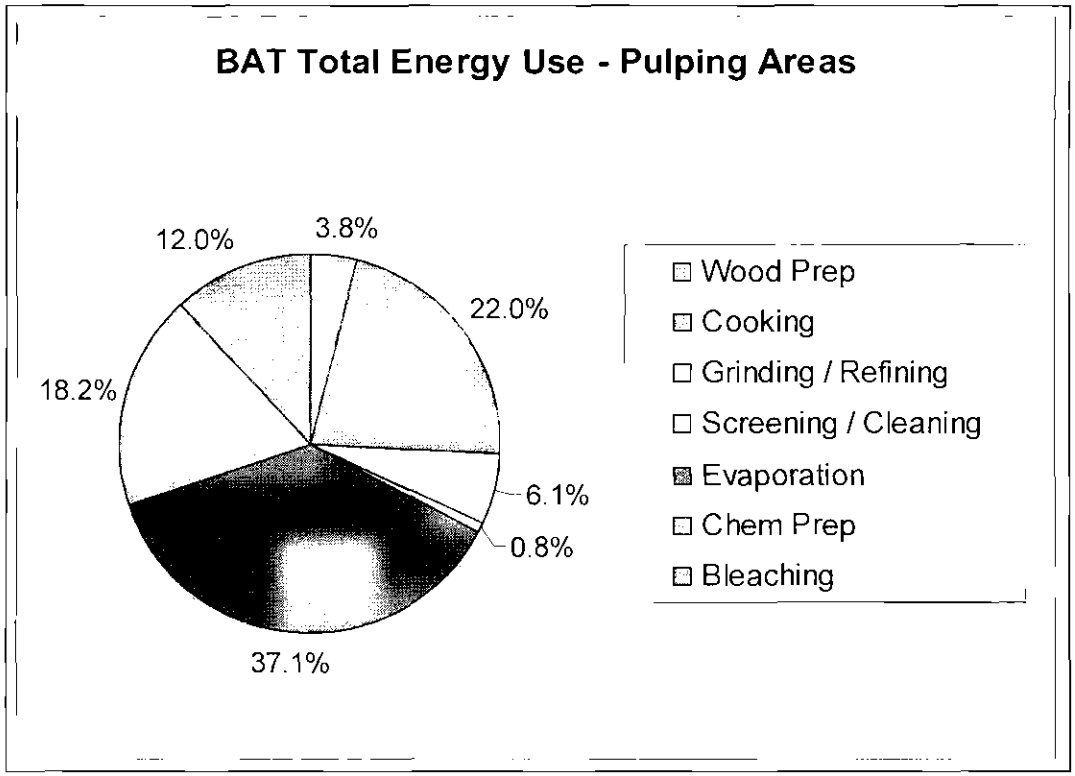
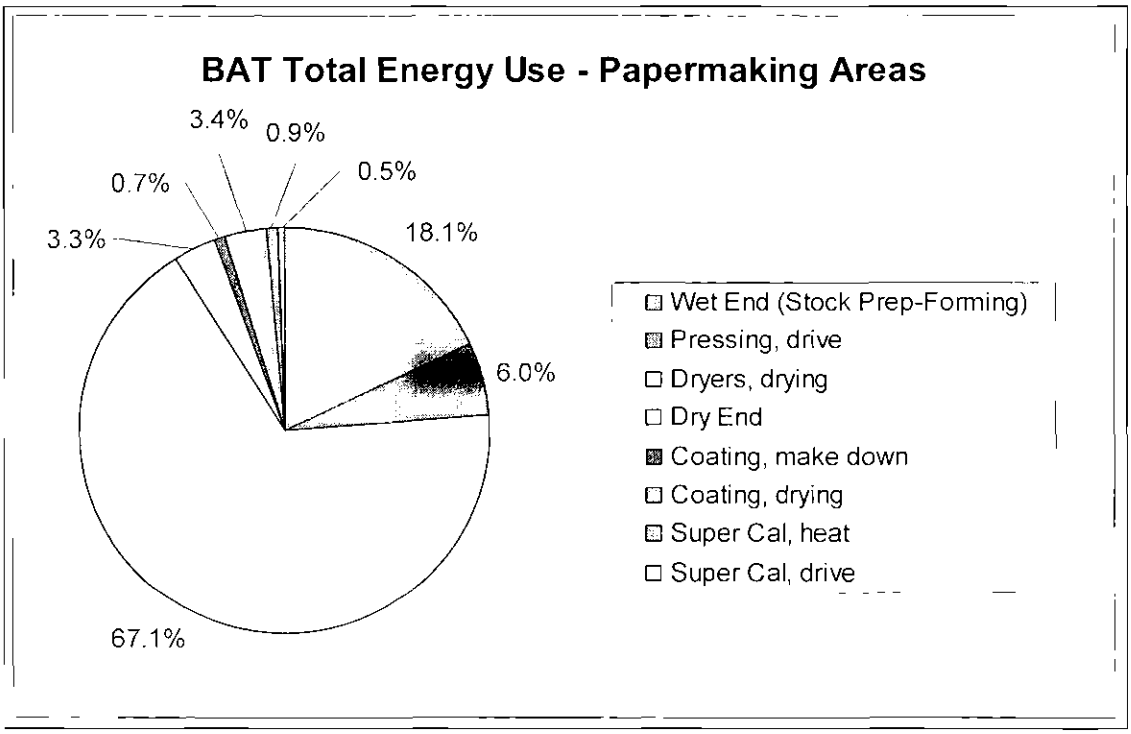


Figure 6.6



Energy consumption in the BAT Hardwood Kraft mill with Printing and Writing, BAT Unbleached Kraft with Linerboard and TMP with Newsprint are shown graphically in Figures 6.7, 6.8 and 6.9, respectively. Figure 6.10 shows the heat balance for a typical modern batch digester system.

Figure 6.7
BAT Bleached Hardwood Kraft Pulp and Printing and Writing Paper

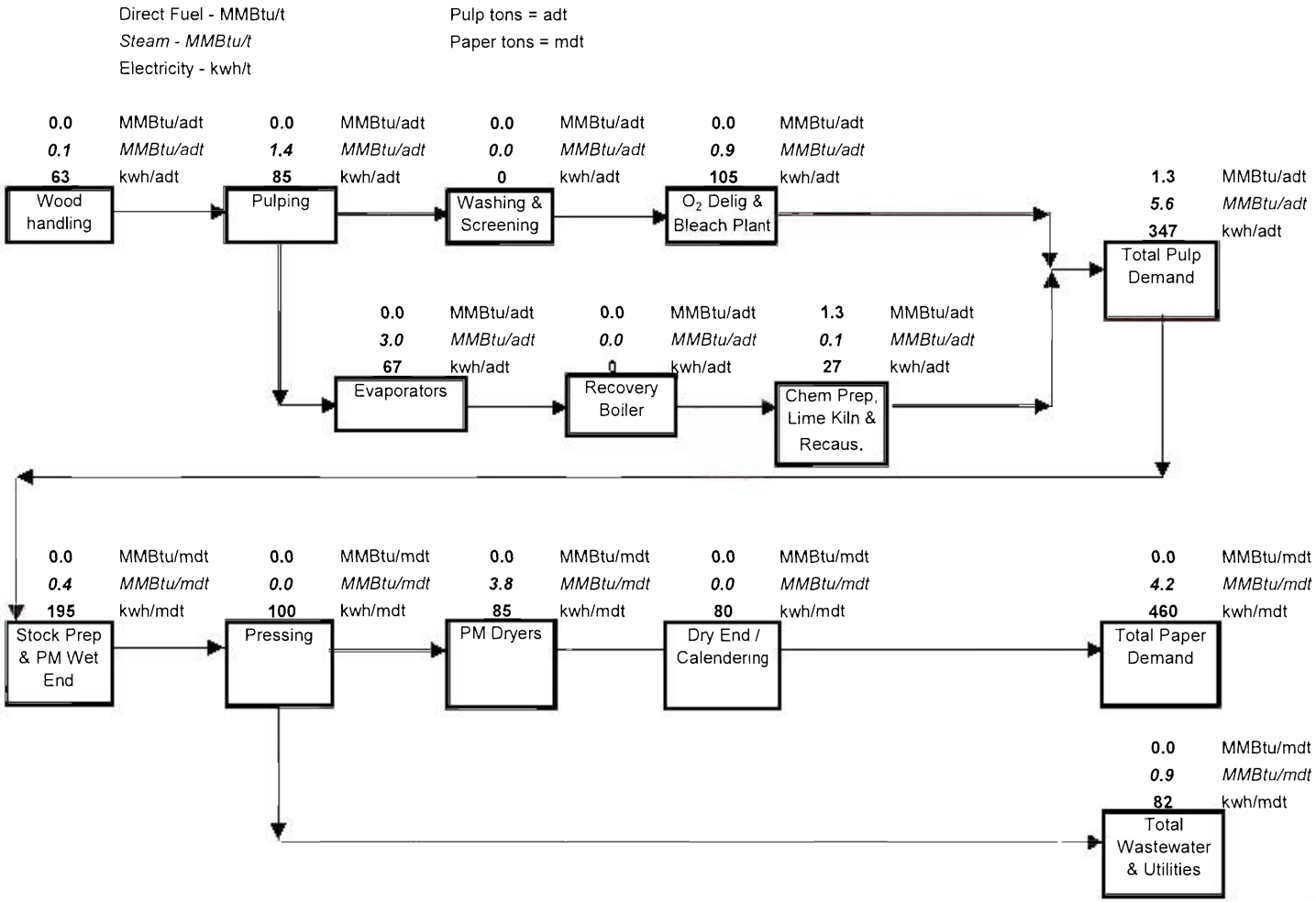


Figure 6.8
BAT Unbleached Kraft Pulp and Linerboard

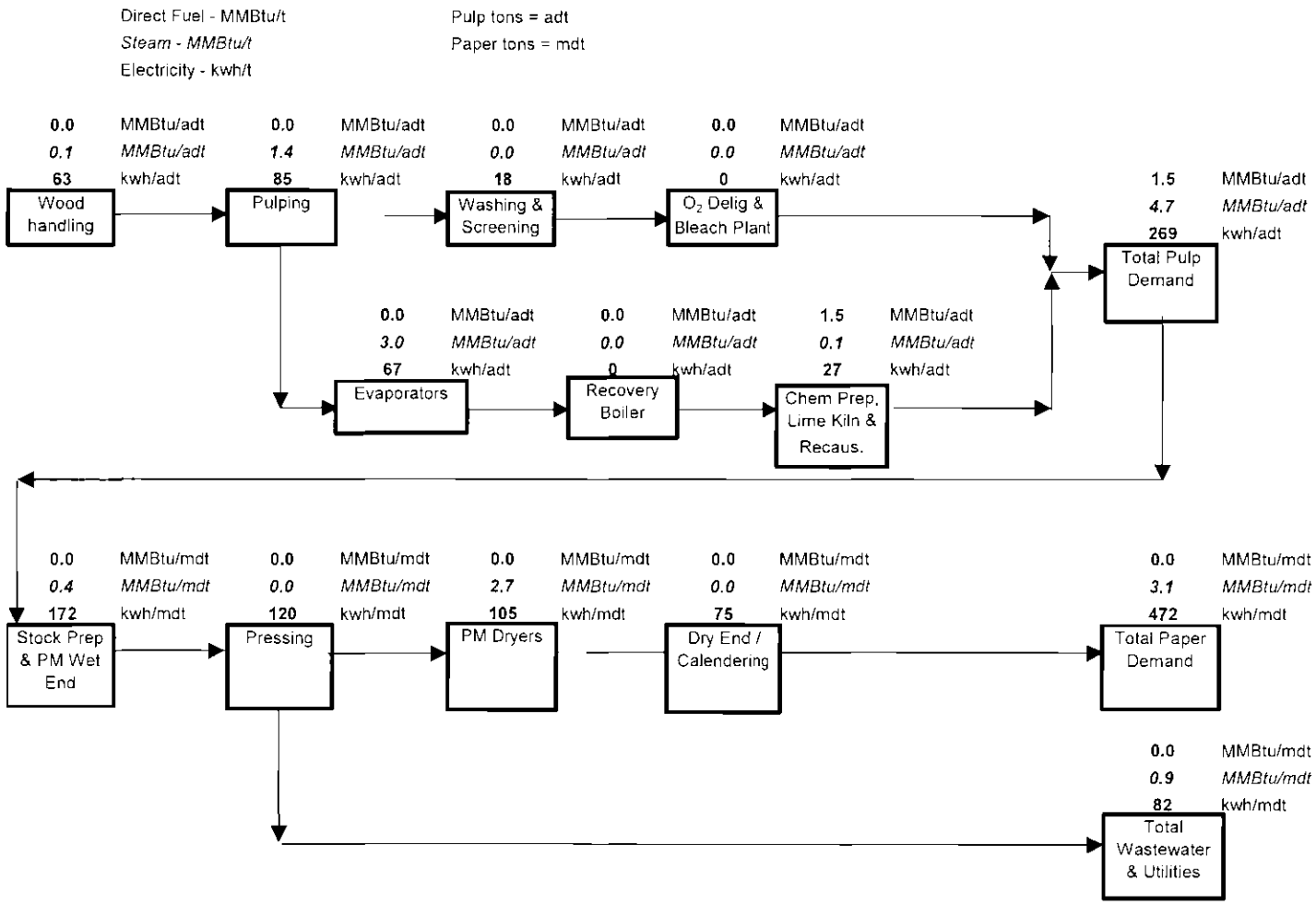


Figure 6.9
BAT TMP and Newsprint

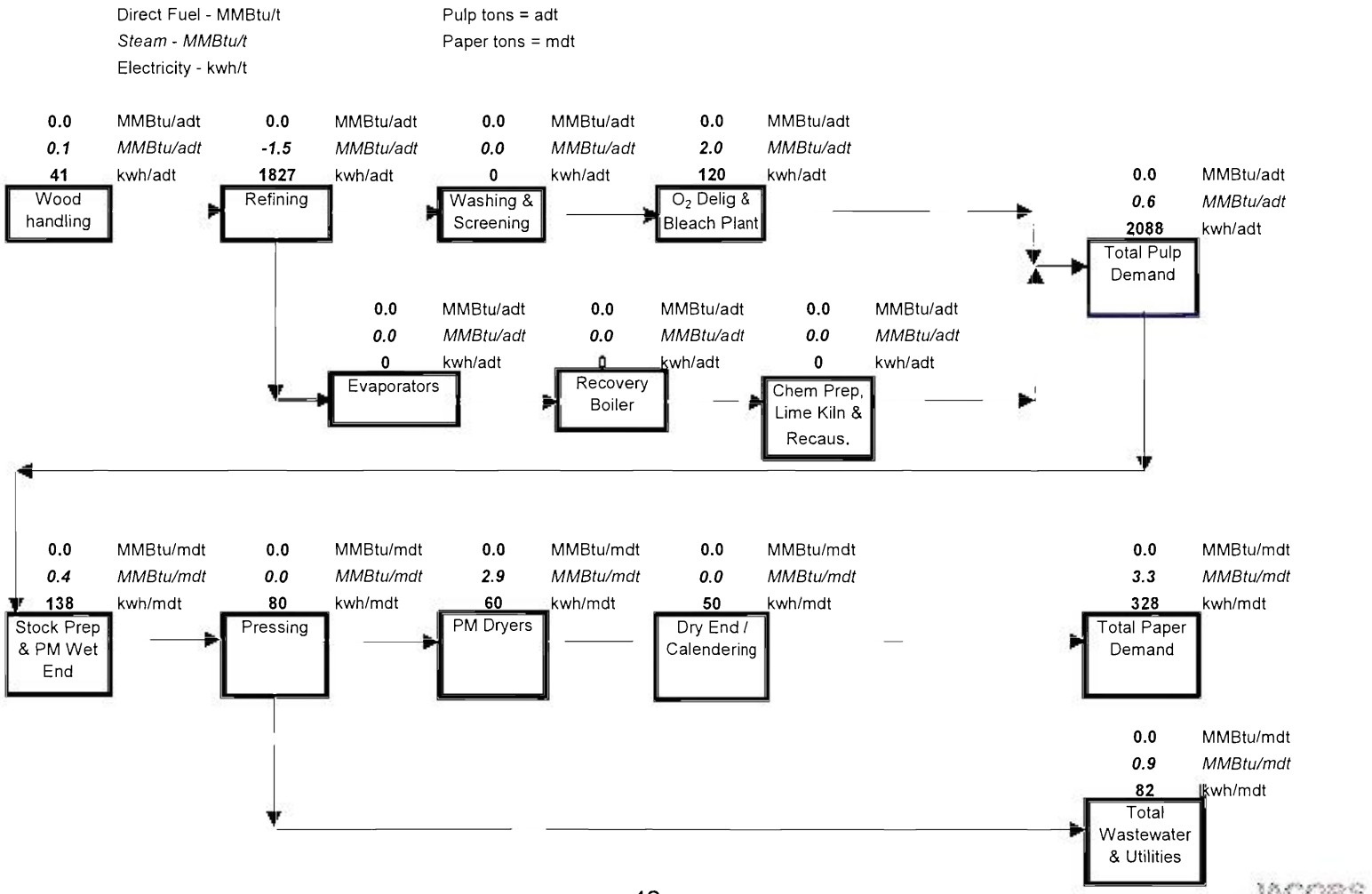
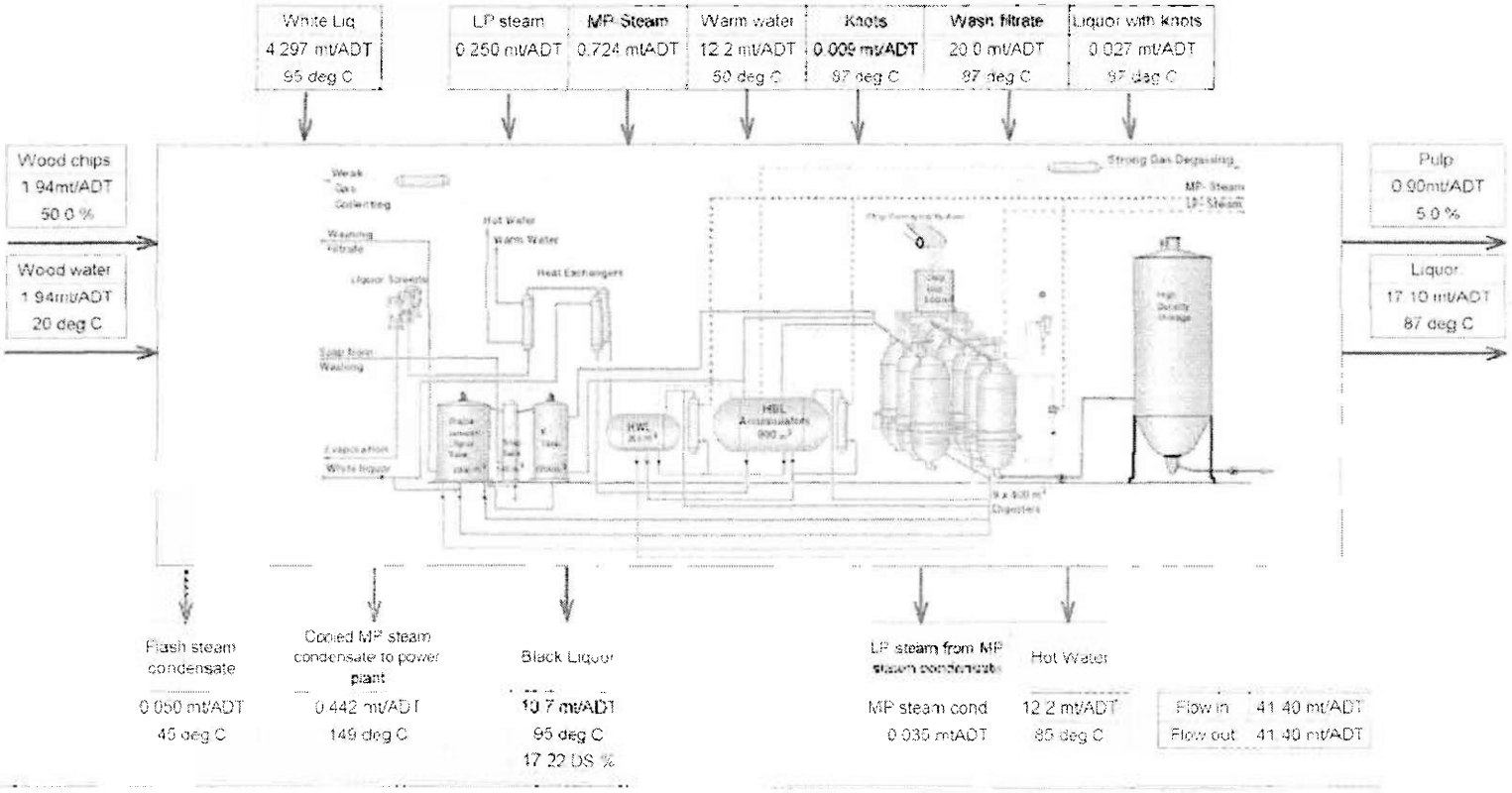


Figure 6.10
Typical Modern Batch Digester System[21]

SuperBatch K, heat and material balance
Softwood, 30 kappa number
Digester plant production: 2800 admt/d

Note: tons shown are metric



7. DESCRIPTION OF A MODERN MILL

The kraft process accounts for almost 57% of the pulp manufacturing capacity and 76% of the pulping energy consumption in the U.S. As shown in Table 3.6 and Figure 4.2 the breakdown for kraft pulp is:

Table 7.1
Kraft Pulping

Type	Pulp Production (% of Total)	Pulping Energy Use (% of Total)
Bleached Hardwood	17.8%	26%
Bleached Softwood	16.0%	24%
Unbleached, mostly softwood	23.0%	28%
Total	56.8%	78%

The energy use shown above does not take into consideration the energy recovered by burning the black liquor in the recovery boiler.

The last greenfield kraft mills built in the U.S. were constructed in the early 1980's. Both were built in association with new printing and writing paper machines. The processes have improved since then; as such, the process for a modern mill is defined and discussed in more detail[22] below.

Area	Equipment	Energy
Wood room	Area where wood is processed for cooking. Wood is received as either chips and/or logs. Chips are prepared off site, generally at a sawmill, and although they generally receive preliminary screening at the source, they typically are re-screened at the mill to remove oversized chips and saw dust. Today most mills receive and process long logs (e.g. logs that are about 60' in length) rather than as short wood (generally about 8' in length). This improves yield by eliminating the need for slashers / cutting log to shorter lengths. Flumes have been eliminated.	Electrical Demand[23]; Debarking: 10 kWh/adt (9.1 kWh/adst) Chipping: 15 kWh/adt (13.6 kWh/adst) Conveying: 20 kWh/adt (18.1 kWh/adst)

Area	Equipment	Energy
	Debarking is done dry, which minimizes the moisture going to the hog fuel boilers. Once the 60' logs are chipped they are conveyed to a storage pile. Conveyors use about 1/3 less energy than pneumatic systems and do less damage to the chips. Chips are screened to eliminate oversized and saw dust. From storage chips are conveyed to the digesters.	
Digesting	Digesting is the area of the mill where chips are "cooked" to convert the chips into fibers. Digesting is one of the major steam consumers in the pulp mill. Modern displacement batch digesters and/or continuous digesters use about ½ of the steam required in conventional batch digesters. The newer systems also produce a more uniform pulp quality, which in turn allows yields to be increased.	Steam[24] - Conventional Batch: 3.5 – 4 GJ/adt (3.0-3.4 MMBtu/adst) Steam - Displacement Batch & Continuous: 1.7-2.5 GJ/adt (1.5-2.1 MMBtu/adst)
Screening and Washing	Today knots and shives are removed in multi stage pressure screens that utilize slots, rather than the older open screens that utilized holes. Modern screens run at higher consistency, thus reducing energy consumption. Washing has evolved from the older design drum washers to more efficient drum washers, displacement washers, pressure washers and belt washers. All have improved washing efficiency and minimize the need for wash/shower water. Minimizing shower water is critical since the evaporators are the largest consumers of steam in the pulp mill. Today the clean condensate from the evaporators is used for showers. Mills balance salt cake loss vs. dilution factor to optimize energy and chemical costs.	

Area	Equipment	Energy
Oxygen Delignification	Oxygen delignification consists of pre-washing (brown stock washing), oxygen mixing, one or two stages reactors, and post-washing. Minimizing cooking liquor carry over is critical to maintaining pulp strength. Generally the reactors are operated at about 85-100°C and utilize medium consistency (12%). (Note: originally systems operated at high consistency (20%+) but have shifted to medium consistency to improve pulp quality) Almost all modern mills utilize O_2 delignification. A worldwide survey conducted in 1997 showed the average delignification for hardwood was 40% and 47% for softwood[25].	Electricity: 75 kWh/adt (68 kWh/adst) Steam: 0.6 GJ/adt (0.5 MMBtu/adst)
Bleaching	Today most modern bleach pulp mills utilize oxygen delignification prior to bleaching. Softwood mills generally utilize a four stage (excluding O_2 Delignification) ODEopDD[2] sequence while hardwood mills utilize a three stage ODEopD sequence. Without O_2 delignification the softwood bleach sequence would be a five stage DEopDED. Elemental chlorine has been eliminated from the bleaching process due to environmental concerns. On an equivalent chlorine (Cl_2) basis, production of sodium chlorate for the generation of chlorine dioxide (ClO_2), production of ClO_2 requires about 17% more electricity that Cl_2. E stage filtrate is used to pre-heat the ClO_2 solution to reduce energy use. D stage filtrate flow is counter current to reduce water usage. Use of wash presses allows efficient washing with minimal shower water use. Bleach effluents as low as 5 m^3/adt (1321 gal/ton) have been achieved[26]. On an overall basis, utilizing O_2 delignification	Electrical Demand/stage: 20-30 kW/adt (18.1-27.2 kWh/adst) Electrical Demand for ODEopDED: 257 kWh/adt (233 kWh/adst)

[2] The following describes the symbols used to define a bleach sequence: O – O_2 delignification; D – chlorine dioxide (ClO_2); E – caustic (NaOH) extraction; small o and p represent oxygen and peroxide reinforcements.

Area	Equipment	Energy
	reduces the electrical consumption of the bleach plant by 99 kWh/adt or about 28%[27].	
Lime Kilns	Lime kilns convert calcium carbonate (lime mud) produced during recausticizing to calcium oxide (lime). They consume approximately 5% of the total fuel used by the industry, including fuel used in the powerhouse. The kiln is a long thermal reactor. Reducing the moisture content of the lime mud is critical to reducing energy consumption. Modern filters have discharge solids of about 80-85% vs. the older units with 65-70% solids. For each 1% increase in solids feeding the kiln, roughly 44 MJ/t (0.4 MMBtu/adst) of lime is saved in evaporation costs.[28] Modern mills have flash dryers following the filters. Today's kilns have electrostatic precipitators in lieu of scrubbers. Although today's kilns utilize significantly less energy per ton of lime (6-7GJ/t) (5.2-6.0 MMBtu/st) than kilns of a few years ago (~11-13 GJ/t lime) (9.5-11.2 MMBtu/st) they still utilize about twice the theoretical energy (3.2 GJ/t) (2.48 MMBtu/st). Lime kilns are also being used to destruct the odorous non-condensable gases (NCG) that are generated during the pulping process. These gases generally have a good fuel value and buring the NCG can reduce the amount of purchased energy used in the kiln.	Direct Fuel: 6-7 GJ/t lime (5.2 - 6.0 MMBtu/st lime) (1.4 - 1.6 MMBtu/adst pulp[3],[29])
Evaporators	Black liquor evaporators typically use the most steam in a kraft mill. Evaporators raise the weak liquor solids generated during washing (~14%) to that required for firing in a recovery boiler. Historically long tube evaporators raised solids to about 50% then the final increase to about 65% was accomplished in the cascade evaporator that utilized the recovery boiler flue gas. Due to air emissions, the cascade evaporator is no	7 Effect: Steam[30]: 390 kJ/kg water (168 Btu/lb) Electricity[31]: 20-30 kWh/adt 18.1-27.2 kWh/adst)

[3] Assuming 480 lbs of active CaO used per ton pulp in the causticizer

Area	Equipment	Energy
	longer an option for a modern mill. Today, a concentrator that utilizes steam to raise solids to as high as 80% has replaced the cascade. Use of multiple evaporative stages (effects) improves the steam utilization efficiency, or steam economy, and reduces total steam demand. A four effect system typically utilizes 670 kJ/kg (288 Btu/lb) of water evaporated and has a steam economy of 3.1 while a 7 effect system utilizes 390 kJ/kg (168 Btu/lb) and has an economy of 5.4. Vapor re-compression evaporative units are also installed that utilize low-pressure steam, typically "waste" steam, and raise the liquor solids prior to the main evaporators.	7 Effect Evap.: 14 to 65% solids; Concentrator: 65 to 80% solids
Recovery Boilers	A recovery boiler separates the organic from the inorganic solids in the black liquor. The inorganic is removed from the boiler as smelt, dissolved in water (forming green liquor) and after recausticizing is reused as pulping liquor (white liquor). Organics are burned to generate steam. Recovery boiler can generate 60-80% of the pulp mill's steam demand[32]. The higher the percent solids fired the greater the amount of steam generated (rule of thumb: 5% increase in solids = 2% increase in steam generation). Keeping a boiler clean improves generation efficiency. The conventional or Tomlinson boiler is used at all kraft mills. Black liquor gasification has been widely discussed as a process to replace the Tomlinson, but today they have seen limited commercial installation. Pressurized gasifiers have the potential to be safer (no smelt) than a Tomlinson and have overall higher energy efficiency. There are three atmospheric gasifiers installed in North America. Two are installed at mills that utilize a carbonate cook to produce pulp for corrugating medium and one is installed at a kraft mill. Steam is used in soot blowers to keep the	

Area	Equipment	Energy
	recovery boiler's tubes and gas passages clean. Fans and feed water pulps are the major consumers of electricity. Modern boilers utilize three or four air systems to insure good mixing within the boiler to minimize liquor carry over (reduces plugging) and minimize emissions of TRS. Historically recovery boilers had steam drum operating pressure that ranged from 600 to 900 psi. Today recovery boilers operate at pressures that range from 1200 to 1500 psi. The higher operating pressure of the Tomlinson high-efficiency recovery boiler (HERB) improves the efficiency of the turbine-generators that are downstream of the recovery boiler. In a case study, the electrical generating efficiency increased to 16.3%[33] vs. 11.9% for a conventional Tomlinson (at 1250 psi).	
Auxiliary Equipment	Historically, kraft mills consumed 70-100 m^3/adt[34] (18,500-26,420 gal/adt) of water. Today a typical mill used 50 – 70 m^3/adt (13,200-18,500 gal/adt). Mills designed for low water consumption can achieve 10 m^3/adt (2,642 gal/adt). In a kraft mill, pumps consume approximately 40-45% of the electrical demand. Demand for fans is another 10-15%, mostly in the kiln, boilers and pulp dryer[35]. Variable speed drives are being used on units with large capacity variations vs. control valves / dampers. Steam stripping of foul condensates is common to remove methanol for the pulp mill effluent. Although the stripper requires as little as 55 MJ/adt (0.05 MMBtu/adst) of steam with an efficiently designed integrated stripper[36], burning the methanol off-gas can result in a net excess energy of 130 MJ/adt (0.11 MMBtu/adst). Wastewater treatment systems consume considerable electrical energy[37,38]. It has been reported that an aerobic-aerobic system	Aerobic: 30-70 kWh/adt (27-64 kWh/adst) Aerobic-aerobic: 35-50% reduction

Area	Equipment	Energy
	can reduce energy by 35-50% from a conventional aerobic system [39],[40]. Captured methane can be used as fuel.	

Modern Papermaking Technology

During the last decade papermaking has undergoing significant changes that affects energy use. These changes will be discussed below.

Area	Equipment	Energy
Stock Preparation	The introduction of slotted screens has reduced sheet breaks and improved quality thus has energy consumption per ton of paper shipped. Additionally, the use of medium consistency fine slotted screening between the blend chest and machine chest, in place of the traditional low consistency hole screen in the thin stock loop, has reduced horsepower required and has in some cases allowed the elimination of centrifugal cleaners.	
	Hybrid conical refiners combine the maintenance efficiencies of disk refiners with the refining efficiency of a Jordan. The impact is reduced energy consumption, about 40% to 70%[41], to develop fibers to the desired quality.	Hybrid refiners: Energy reduction 40-70%
	Compact wet ends / stock systems, such as systems by POM[42], significantly reduce the energy requirements by reducing pumping and agitation requirements. Systems also reduce the grade change time and as such reduce the amount of stock loss and off standard, again reducing the overall energy required per ton of product shipped.	Compact Wet End: Energy reduction about 25%[43] under certain conditions
	Variable speed pumps are used in lieu of constant speed pumps and control valves, which reduces energy consumption. Variable spend pumps are generally used for applications greater than 50 Hp.	

Area	Equipment	Energy
Forming	Twin wire or gap formers are the technology for all high-speed paper machines. This technology applies to printing and writing, tissue, newsprint and board grades. Multi layered sheet forming allows the optimization of fiber resources, allowing the minimization of basis weight. All twin wire formers require mist removal systems that utilize fans, an energy change from traditional flat fourdrinier machines. Historically, adjusting the slice screws across the face of the headbox was used to control the basis weight profile. Modern machines use a system to vary the consistency across the width of the headbox to control basis weight. This system significantly improves the basis weight profile and allows basis weight to be optimized for the desired physical paper properties, thus reducing the overall energy efficiency. Double doctors installed on the couch generally improve solids by 2-3%[44], which equates to a 1% improvement in solids exiting the press section. Compact wet ends including use of inline de-aeration allows for the reduction of water volume and can reduce overall water use.	Flat Fourdrinier[45]: 10-12 kWh/t (9-11 kWh/adst) Twin Wire: 5 kWh/t less (4.5 kWh/adst)
Pressing	Shoe presses are standard on all grades. Historically the shoe press was introduced in the early 80's and was applied to board grades. However, today, they are the press of choice for newsprint and printing and writing grades, and are starting to be used for tissue grades. The high loading and long press nip improve water removal vs. traditional suction / venta-nip presses and even long nip presses popular on board grades in the 70's. Shoe presses generally achieve exiting sheet consistencies to range between 45-50%, significantly dryer than a traditional Tri-nip press section with consistencies of about 40%. Rule of thumb	

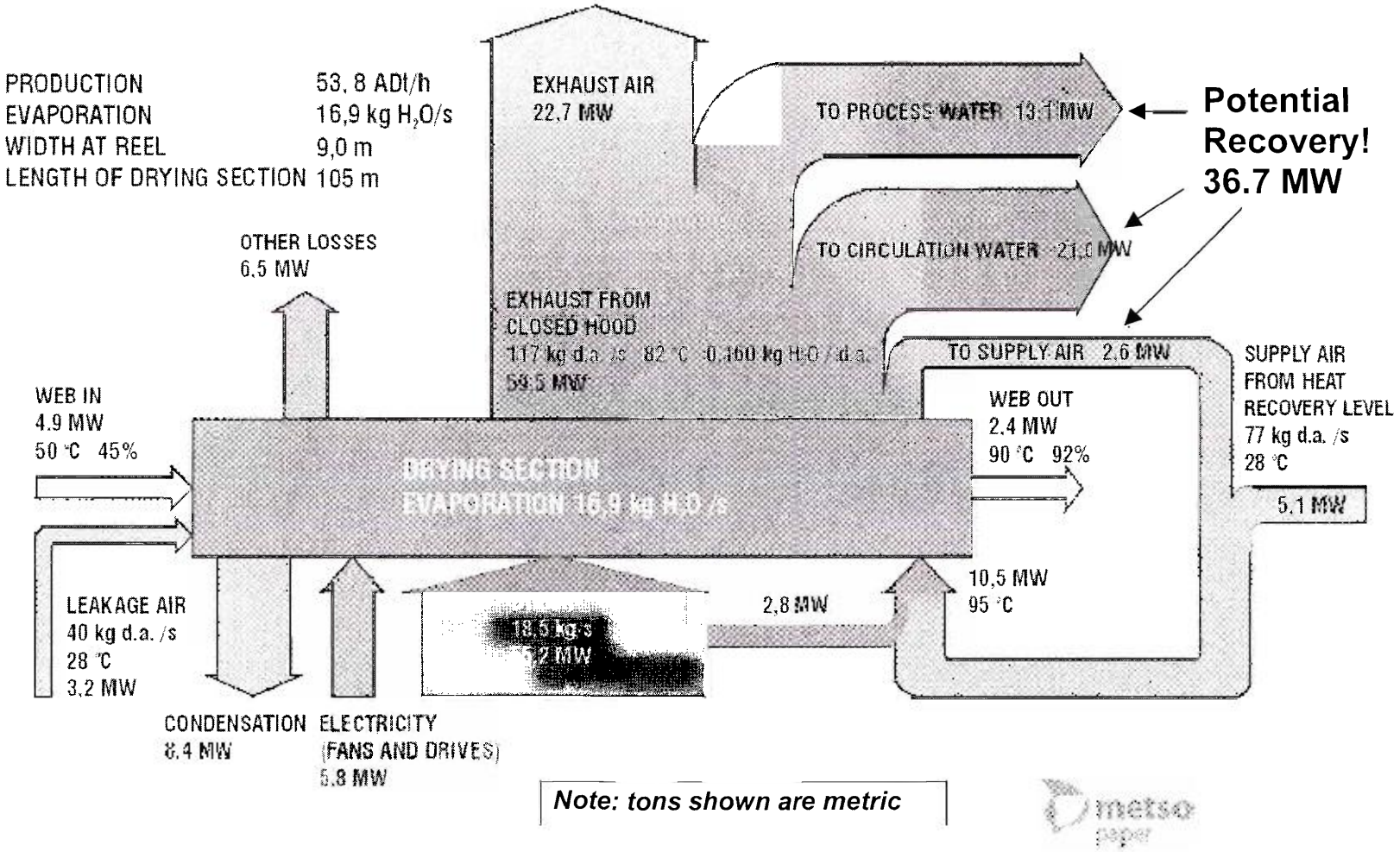
Area	Equipment	Energy
	for every 1% improvement in press consistency equals 4% improvement is drying efficiency. Modern press sections also utilize steam boxes to improve water removal as well as improve moisture profiling, again improving the overall energy efficiency of the paper machine. Trends towards use of higher ash content in the furnish/sheet have also been shown to result in higher exiting press solids.	
Drying	Drying efficiencies have been improved through changes in the design of dryer felts, which has eliminated the need for steam heated felt dryers. Today's felts also allow the water evaporated from the paper to be removed more efficiently. Dryer felt tensions have also been increased from historical tensions of about 7 pli to 14 pli. General rule of thumb, every 1 pli increase is equal to 0.7% improvement in drying efficiency[46],[47]. Modern, high-speed paper machines generally use single tier dryer sections while slower machines use historical two-tier arrangements. Close clearance stationary siphons in dryers vs. rotary siphons reduce the amount of condensate levels in the dryer can improve the thermal efficiency and reduce the required differential pressure. Stationary siphons generally have about 5-10% improved energy efficiency. All modern dryer sections have closed, high efficiency hoods. Assuming that an energy demand of 2.83 MJ/kg (1,217 Btu/lb) of evaporated water (MJ/kg_w) can be reached, the energy needed for drying from 50% to 90% is 2.64 GJ/ADmt (2.27 MMBtu/adst) of paper produced.[48]	

Area	Equipment	Energy
Tissue Drying	Good performance for tissue machine drying steam and gas usage is 6.0 MMBtu/ton tissue. Low energy users utilize 4-5 MMBtu/ton[49] tissue. TAD (Through Air Dried) machines typically use significantly more energy per kg of product than conventional Yankee machines. This is because more water is dried and less is mechanically pressed from the sheet.	
Surface Treatment	For grades that require surface treatment, such as starch sizing for printing and writing, the use of metering blade size presses vs. the traditional puddle presses allows for higher starch solids to be applied. Traditionally solids were in the 1-2% range. Metering blade units allow application of 8% solids, greatly reducing water that must be evaporated in the after drying section.	
Calendering	The introduction of on-line "super calenders" has eliminated the need for off machine super calenders for many grades. These units are more efficient and eliminate the need for rereelers.	
Drives	Until the mid 60's steam turbines and line shafts drove almost all paper machines. During the 70's sectional electric DC drives were the power of choice. Since the 80's AC drives have been the system of choice. An advantage of AC drives is the elimination of auxiliary fan driven motor cooling system. Elimination of the small, inefficient low-pressure turbines has also allowed steam to be used in the powerhouse in more efficient high-pressure turbine-generators.	
Auxiliary Systems	Vacuum pumps use a significant quantity (10-15%) of a paper machine's electrical requirements. A considerable amount of the energy consumed by a liquid ring vacuum pump is transferred to the seal water. For a closed mill, this means the water must be cooled before reuse. Use of multi-stage	

Area	Equipment	Energy
	centrifugal blowers in place of liquid ring vacuum pumps can reduce energy use and eliminate the need for seal water. Water consumption for modern machines is about 530-5,300 gallons/ton vs. historical water consumption in excess of 10,000 gallons/ton. Mills generally heat incoming fresh water, using low-pressure steam, to temperatures about 140°F for process applications: showers, etc. It is estimated that every 1000 gallons of water used is equivalent to 1700 Btus, combining electric and steam energy requirements. Modern machines use heat recovery systems to minimize energy use. An example of the potential is shown in Figure 7.1. Systems such as circulating glycol systems can move "waste heat" from one area of the mill to another area for reuse.	
HD Stock Storage	Conventional high-density (HD) storage towers (tanks) consume significantly more horsepower than San-Ei towers. A traditional 500 ton storage tower typically utilizes a 200 Hp agitator vs. 10 Hp for a San-Ei Regulator tower[50].	

Figure 7.1 shows Metso's Sankey diagram for a modern paper machine dryer hood. It shows the potential for heat recovery.

Figure 7.1
Metso's Energy Sankey Diagram for a Conventional (SymRun) Drying Section[51]



8. PRACTICAL MINIMUM ENERGY CONSUMPTION

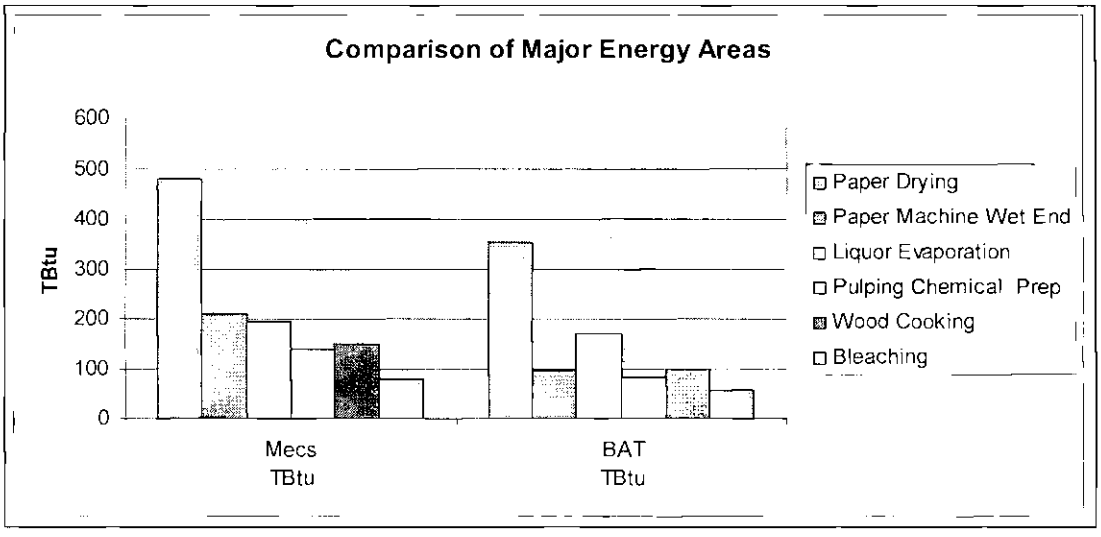
Areas of Opportunity

The six major energy users within the U.S. pulp and paper industry are shown in the Table 8.1 and Figure 8.1.

Table 8.1
Major Energy Consumption Areas

Area	MECS Energy Consumption TBtu	MECS Percent of Total %	BAT Energy Consumption TBtu	BAT Percent of Total %
Paper Drying	481	32.4	354	34.2
Paper Machine Wet End	211	14.2	95	9.2
Liquor Evaporation	195	13.1	171	16.5
Chem. Prep including Lime Kiln	140	9.4	84	8.1
Pulp Digesting	149	10.0	101	9.8
Bleaching	80	5.4	55	5.3
Other Processes	228	15.4	175	16.9
Process Total	**1,484**	100.0	**1,035**	100.0

Figure 8.1



Energy Consumption – Practical Minimum Requirements

Paper Drying

Modern press sections, using a shoe press, have exiting moistures that typically range from 45 to 50%. Based on the analyses reported earlier in this report, average drying requirements were estimated at 4.5 MMBtu/fst and BAT at 3.8 MMBtu/fst (Figures 4.6 and 6.7).

Calculation of Practical Minimum energy consumption in drying was based on press section dewatering to 65% solids[52] followed by drying of the remaining water at a steam usage of 1.3 lbs steam per lb water evaporated. Result is an estimated steam usage of 1.3 MMBtu/fst. The 65% exiting press solids is based on previous laboratory work indicating achievement of exiting solids around that level under certain optimized pressing conditions[53].

Water removal by pressing is ultimately limited to about 70%, due to the amount of water contained within the fiber cell itself. Based on exiting solids of 70%, the theoretical dryer energy required was calculated to be 0.88 MMBtu/fst[54]. (This calculation is based on energy required to heat the water and fiber, to evaporate the water, and to desorb the water; calculations are included in the APPENDIX. If the solids were raised to 70%, then the potential energy reduction for drying is 79%. Figure 8.2 shows the minimum theoretical drying energy required at various exiting press solids. The summary chart showing average, BAT, Practical Minimum, and Theoretical Minimum drying energy required is shown in the Summary section below.

Figure 8.2

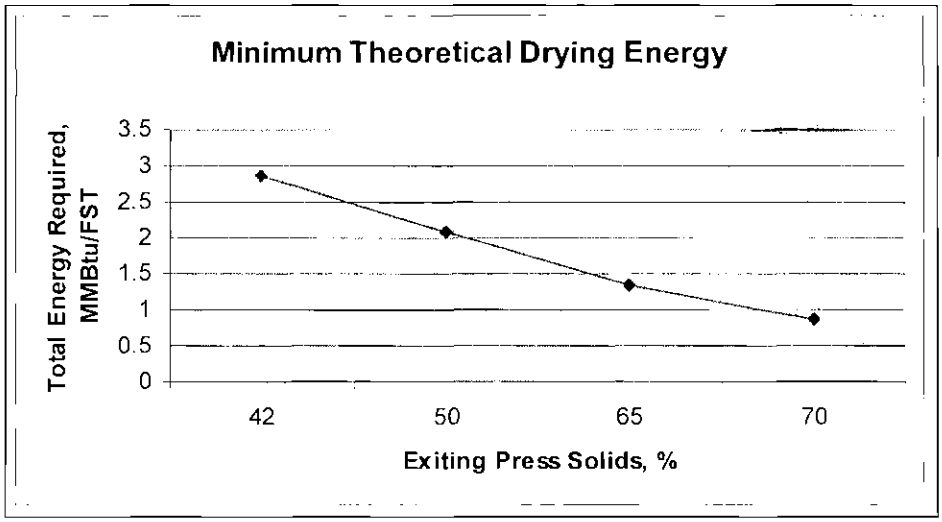
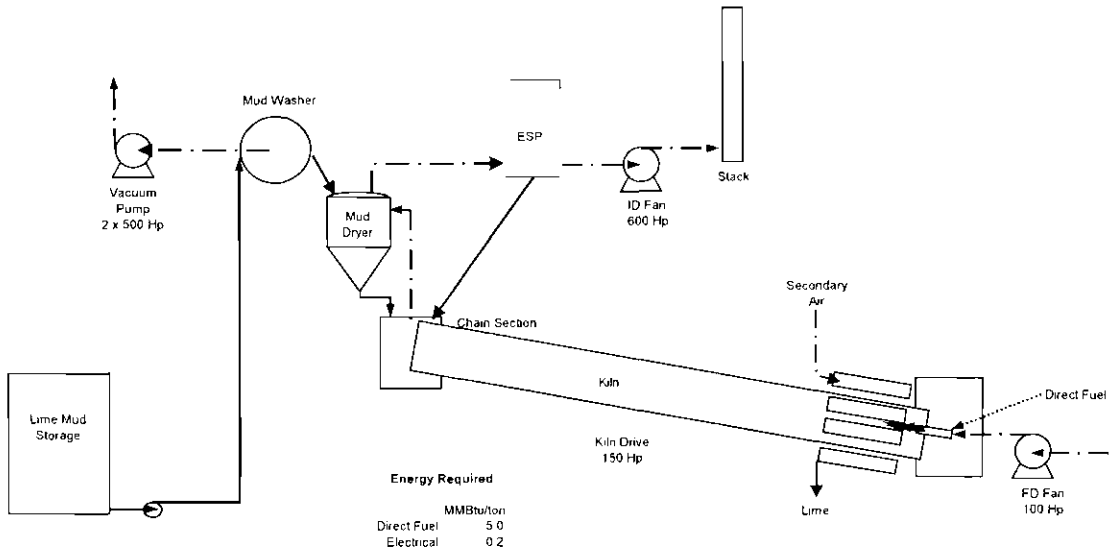


Figure 8.3
Example of a Modern Lime Kiln System



Lime Kiln

Theoretical energy, based on endothermic reaction, requires 2.48 MMBtu/t[55] lime while a modern kiln, BAT based on lime kiln manufactures design data, requires about 5.0 MMBtu/st lime (approximately 1.34 MMBtu/adst of pulp assuming 480 lbs of active CaO used per ton pulp in the causticizer[56]). Jaakko Pöyry reported[57] that some mills are using about 1.15 GJ/Adt (1.0 MMBtu/adst) fuel in their kilns. Mills producing tropical hardwoods, with oxygen delignification, higher yields and lower alkali charges can achieve low kiln fuel use on a pulp ton basis. Based on the theoretical energy requirements, the opportunity to reduce direct fuel from design BAT is about 35%. Above and beyond the direct fuel in a kiln there is a requirement for electricity for forced draft (FD) and induced draft (ID) fans, electrostatic precipitators (ESP), vacuum pumps and the kiln drive plus a host of smaller requirements for pumps and conveyors. Electrical energy adds an estimated 0.04 MMBtu/adst. Current commercial designs generally use either an external mud dryer or an efficient chain section to utilize the waste (flue gas) heat to dry the mud entering the kiln. Generally both systems are not used due to dusting and installation costs. Figure 8.3 illustrates a typical modern kiln system. Comparison of the two approaches is shown Table 8.2.

Energy consumption saving in new kilns vs. an older kiln with modern internals is about 8% to 17%. Energy savings for new kiln design vs. conventional kilns is about 25%. Going with auto causticizing eliminates the kiln and auxiliary equipment, including the direct fuel and electrical load. Partial auto causticizing is being done at several mills in the U.S. and Europe.

Figure 8.9 compares the energy requirements using different technologies. Practical Minimum Technology is the energy consumption at 35% of today's new kilns (design BAT), however the potential saving using the Jaakko Pöyry numbers is only 14%.

Table 8.2
Lime Kiln Design Comparison[58]

System Type	Production Factor Ft^3/st/day	Relative Heat Rate* MMBtu/st lime (MMBtu/adst pulp)	Relative Power Consumed* KWh/st lime (MMBtu/adst pulp)
Conventional Long Kiln	100	7.0 (1.87)	67 (0.061)
Long Kiln retrofitted with modern internals	73-78	6.0 (1.60)	63 (0.056)
New Long Kiln with modern internals, product cooler and ESP	70-75	5.0 (1.34)	45 (0.040)
Kiln with external dryer system and with modern internals, product cooler and ESP	55-60	5.5 (1.47)	50 (0.045)

* Mud feed at 75% solids

Evaporators

Liquor evaporation accounts for almost 12% of the energy consumed during pulp and paper manufacture. Based on the analyses reported earlier in this report, average black liquor evaporation steam requirement was estimated at 3.5 MMBtu/adst and BAT at 3.0 (Figures 4.6 and 6.7, respectively).

Calculation of Practical Minimum energy consumption in evaporation was based on use of membrane technology to dewater from 22 to 30% black liquor solids (recent work having demonstrated use of ultrafiltration to concentrate black liquor to over 30% solids), followed by multiple effect evaporation to 80% solids[59]. Result is an estimated steam usage of 2.2 MMBtu/bdst (Table 8.5). Assumptions for the calculation include:

- Sensible heat increase taken into account
- Latent heat of vaporization is obtained by dividing by number of effects to take into account use of vapor to heat subsequent effects.
- Heat Transferred = Heat usage (heat sink) = Sensible Heat to Bring Liquor to Boiling Temp + Latent Heat of Vapor Produced (Water Evaporated)/(number of effects)

Electrical power requirement in the membrane separation step was estimated at 16 kWh/adt[60], which compares favorable with the overall average case power requirement of 40 kWh/adt (Figure 4.6). The summary chart, Figure 8.8, shows average, BAT, Practical Minimum and Theoretical Minimum cases which are described in Tables 8.3 thru 8.6.

Table 8.3
Average Evaporation Energy - Estimate

Weak black liquor (WBL) solids, WBLS	14	%	13-15% is "average"; 17% is Bat with drum washers considering soda loss / energy balance
Solids out	65	%	70% "good"; range 62-80%, BAT is 80%
Number of effects	5.5		Industry average is somewhere between 5-6 effects. Also, assume that evaporation in each effect is the same. Note we are not taking steam economy into account directly (steam economy = (0.8)N where N=5.5. This would give Steam Economy =4.4, which is close to design; actual can be only 70% of that.)
Amount BL solids/unit amount pulp, Wli	3,200	lb BLS/BDmt	Reference[61],[62]
Specific Heat of WBL, Cpl	0.8	Btu/lb °F	Reference[63]
Product liquor from first effect, Tb	250	°F	
Liquor feed temp, Ti	200	°F	
Average latent heat of steam for entire evaporator set, λb	980	Btu/lb	
Sensible heat to bring liquor to boiling temperature.	914,286	Btu/BDmt	Mass of BL entering evaporator X BL specific heat X (liquor boiling T entering vapor head - liquor inlet T)
Latent heat of vapor produced (water evaporated)/(no. effects)	3,195,524	Btu/BDmt	Vapor produced (water evaporated) X latent heat of steam at boiling conditions
Total energy required	4,109,810	Btu/BDmt	
	3.4	MMBtu/adst	

Table 8.4
Practical Minimum Evaporation Energy (with Membrane)

Weak black liquor (WBL) solids, WBLS	30	%	13-15% is "average"; 17% is Bat with drum washers considering soda loss / energy balance
Solids out	80	%	70% "good"; range 62-80%, BAT is 80%
Number of effects	3.2		Also, assume that evaporation in each effect is the same. Note we are not taking steam economy into account directly (steam economy = (0.8)N where N=7. This would give Steam Economy =5.6, which is close to design; actual can be only 70% of that.)
Amount BL solids/unit amount pulp, Wli	3,200	lb BLS/BDmt	Reference[64] [65]
Specific Heat of WBL, Cpl	0.8	Btu/lb °F	Reference[66]
Product liquor from first effect, Tb	275	°F	
Liquor feed temp, Ti	200	°F	
Average latent heat of steam for entire evaporator set, λb	980	Btu/lb	
Sensible heat to bring liquor to boiling temperature	640,000	Btu/BDmt	Mass of BL entering evaporator X BL specific heat X (liquor boiling T entering vapor head - liquor inlet T)
Latent heat of vapor produced (water evaporated)/(no. effects)	2,041,667	Btu/BDmt	Vapor produced (water evaporated) X latent heat of steam at boiling conditions
Total energy required	2,681,667	Btu/BDmt	
	2.2	MMBtu/adst	

Table 8.5
Theoretical Minimum Evaporation Energy (without Membrane)

Weak black liquor (WBL) solids, WBLS	17	%	13-15% is "average"; 17% is Bat with drum washers considering soda loss / energy balance; belt washer could be higher than 17%
Solids out	80	%	70% "good"; range 62-80%, BAT is 80%
Number of effects	7		Also, assume that evaporation in each effect is the same. Note we are not taking steam economy into account directly (steam economy = (0.8)N where N=7. This would give Steam Economy =5.6, which is close to design; actual can be only 70% of that.)
Amount BL solids/unit amount pulp, Wli	3,200	lb BLS/BDmt	Reference[67] [68]
Specific Heat of WBL, Cpl	0.8	Btu/lb °F	Reference[69]
Product liquor from first effect, Tb	275	°F	
Liquor feed temp, Ti	200	°F	
Average latent heat of steam for entire evaporator set, λb	980	Btu/lb	
Sensible heat to bring liquor to boiling temperature	1,129,412	Btu/BDmt	Mass of BL entering evaporator X BL specific heat X (liquor boiling T entering vapor head - liquor inlet T)
Latent heat of vapor produced (water evaporated)/(no. effects)	2,075,294	Btu/BDmt	Vapor produced (water evaporated) X latent heat of steam at boiling conditions
Total energy required	3,204,706	Btu/BDmt	
	2.6	MMBtu/adst	

Table 8.6
Theoretical Minimum Evaporation Energy (with Membrane)

Weak black liquor (WBL) solids, WBLS	30	%	13-15% is "average"; 17% is Bat with drum washers considering soda loss / energy balance
Solids out	80	%	70% "good"; range 62-80%, BAT is 80%
Number of effects	4		Also, assume that evaporation in each effect is the same. Note we are not taking steam economy into account directly (steam economy = (0.8)N where N=7. This would give Steam Economy =5.6, which is close to design; actual can be only 70% of that.)
Amount BL solids/unit amount pulp, Wli	3,200	lb BLS/BDmt	Reference[70] [71]
Specific Heat of WBL, Cpl	0.8	Btu/lb °F	Reference[72]
Product liquor from first effect, Tb	275	°F	
Liquor feed temp, Ti	200	°F	
Average latent heat of steam for entire evaporator set, λb	980	Btu/lb	
Sensible heat to bring liquor to boiling temperature	640,000	Btu/BDmt	Mass of BL entering evaporator X BL specific heat X (liquor boiling T entering vapor head - liquor inlet T)
Latent heat of vapor produced (water evaporated)/(no. effects)	1,633,333	Btu/BDmt	Vapor produced (water evaporated) X latent heat of steam at boiling conditions
Total energy required	2,273,333	Btu/BDmt	
	1.9	MMBtu/adst	

Technologies that Can Help Achieve Practical Minimum Energy Consumption

Energy savings technologies that have been evaluated in the laboratory and/or have been commercially applied in a very limitedly fashion are:

- High consistency forming

  High consistency forming was first introduced in the late 1960s when the industry was concerned about the cost of wastewater treatment. Development activities occurred in both the United States and Finland. There

was at least one application in the US that was designed to operate over 10% but did operate at about 8%.

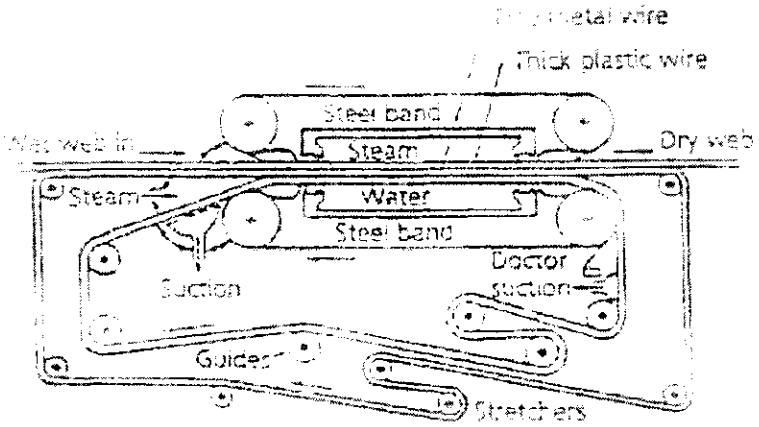
Currently there are a couple of machines producing milk carton that are forming the sheets with consistencies about 4%. Traditional paper machines generally form sheets between 0.5% and 1%, while tissue / towel machines operate with consistencies under 0.2%.

Potential is the reduction in water use and thus energy consumption to a small extent.

- CondeBelt™ drying

Metso developed the CondeBelt™ drying system in the early 1990's, but it has seen limited commercial application. (It has been operating in mills in Europe and Korea.) The system was originally designed as an alternative to a Yankee Dryer for high speed coated board machines. The system utilized two continuous rotating steel belts. One is heated and the other is cooled, creating a high delta T between them and thus a high drying rate. Figure 8.4 is a schematic[73] of the CondeBelt™.

Figure 8.4
CondeBelt™



- Hot impulse pressing

R&D work has shown the potential to improve the consistency of a sheet exiting the press section by the use of a hot impulse press. However, work has also shown the press is capable of generating sufficient steam pressure

within the sheet while in the press nip that upon exiting the nip the steam, now not confined, tends to explode the sheet. This is a significant problem with heavy weight sheets, such as linerboard.

- Black Liquor and Hog Fuel Gasification

There have been several demonstration and commercial units built for both liquor and hog fuel gasification. All existing units in the United States have been atmospheric units. Initial work has identified significant improvement in energy efficiency if a pressurized gasifier were connected to a combined cycle gas turbine. Electrical generating efficiency of a Tomlinson HERB is 16.3% vs. 21.1% for a mill scale high-temperature gasifier[74]. Black Liquor provides 20-25 GJ/admt[75] (17.2-21.5 MMBtu/adst) of energy. Figure 8.5 is a sketch of a Kvaerner (Chemrec) Type pressurized black liquor gasifier system[76]. A pressurize pilot gasifier unit is located in Sweden[77].

Figure 8.5
Pressurized Black Liquor Gasifier

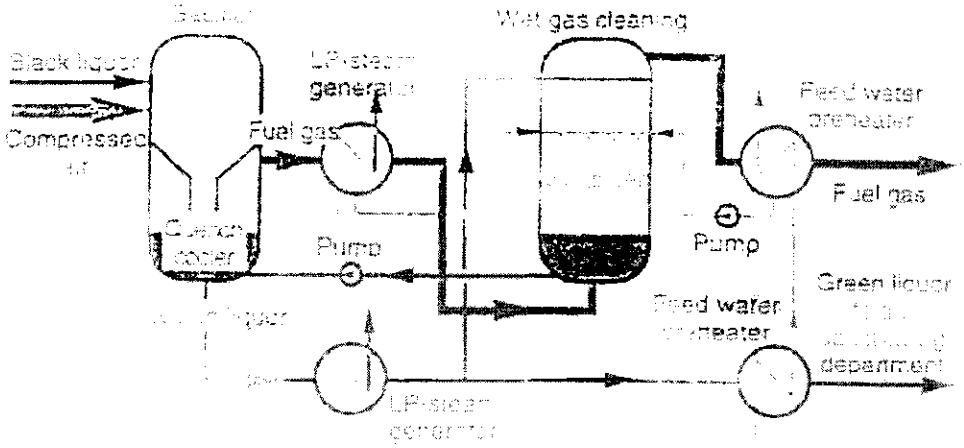
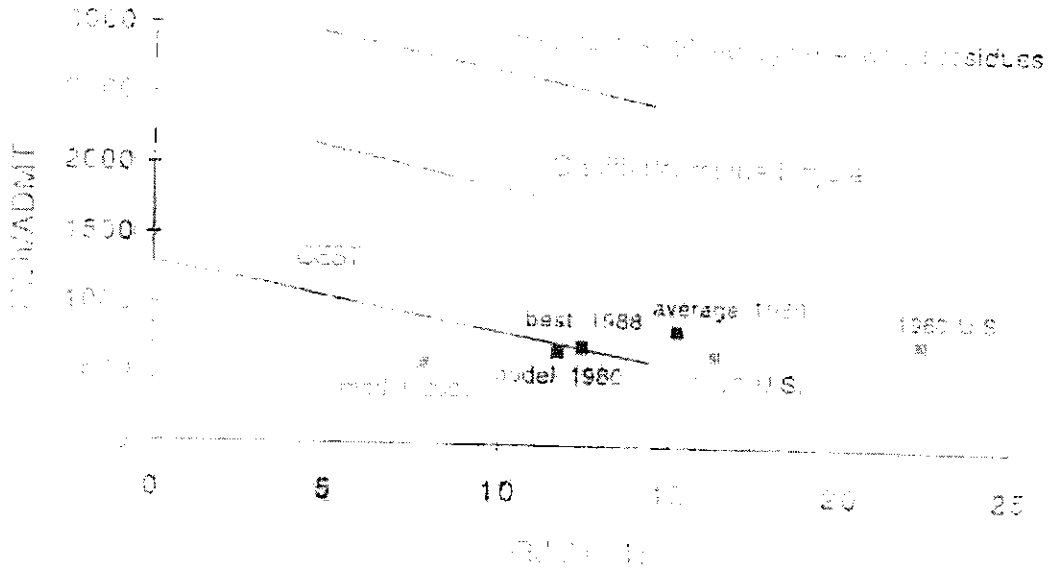


Figure 8.6[78] shows the potential production of steam and electrical (net of cogeneration plant) at a kraft mill from bark (4 MJ/admt) (3.4 Btu/lb) and black liquor (21 MJ/admt) (18.1 Btu/lb) fuels using alternative cogeneration technologies. The cogeneration technologies are the condensing extraction steam turbine (CEST) and the black liquor/bark integrated gasification/gas turbine combined cycle (liquor and bark are burned separately). For the later technology two lines are shown. The upper line assumes the use of 8 MJ/admt (6.9 Btu/lb) of forest or other biomass residues in addition to the 25 MJ/admt (21.5 Btu/lb) of fuels assumed for the lower line[79].

Figure 8.6
Steam and Electricity Production Potential



- Auto causticizing

  Auto causticizing is theoretically viable and has been demonstrated in the lab. Elimination of the lime kiln and all the associated causticizing equipment would save significant energy. The lime kiln in many kraft mills is the major consumer of direct (fossil) fuels. Commercialization has been hindered by the cost of the required catalysts, however there are several mills in the U.S. and Europe running partial auto causticizing. Auto causticizing can be coupled with black liquor gasification. Current research[80] indicates Titanates work at high temperature and pressure while Borates work at low temperature and pressure. The Borate systems can be used for partial conversions (booster systems to augment existing capacity) while Titanates can be used for 100% conversion, i.e. eliminate the lime kiln.

- Biorefinery

  Much has been discussed about biorefinery concept in recent years[81],[82]. It was a subject mentioned in President Bush's 2006 State of the Union Address. It is a component of AF&PA's Agenda 2020. Extracting hydrogen, and other chemical feed stock, from wood chips prior to pulping has the potential for a significant change in the way pulp mills utilize / produce energy. Net energy efficiency impact of a biorefinery is currently being investigated[83].

Summary

Figures 8.7, 8.8 and 8.9 graphically show the comparison of current energy consumption vs. BAT, Practical Minimum and Theoretical Minimum energy consumption of the paper drying, liquor evaporation and lime kiln respectively. The potential energy savings, i.e. bandwidth, between BAT and Practical Minimum are: Paper Drying – 66%, Liquor Evaporation – 27% and Lime Kiln – 35%.

Figure 8.7

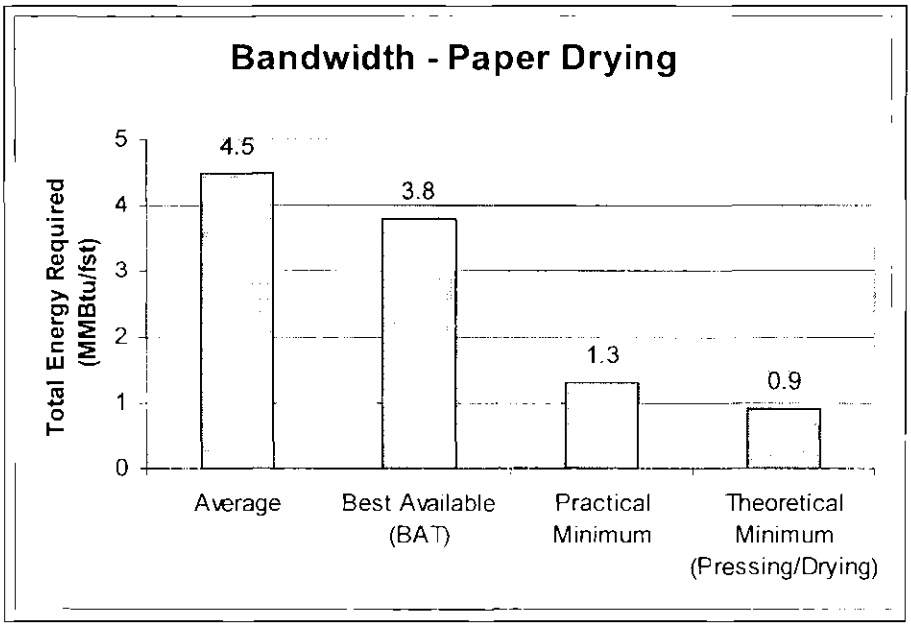


Figure 8.8

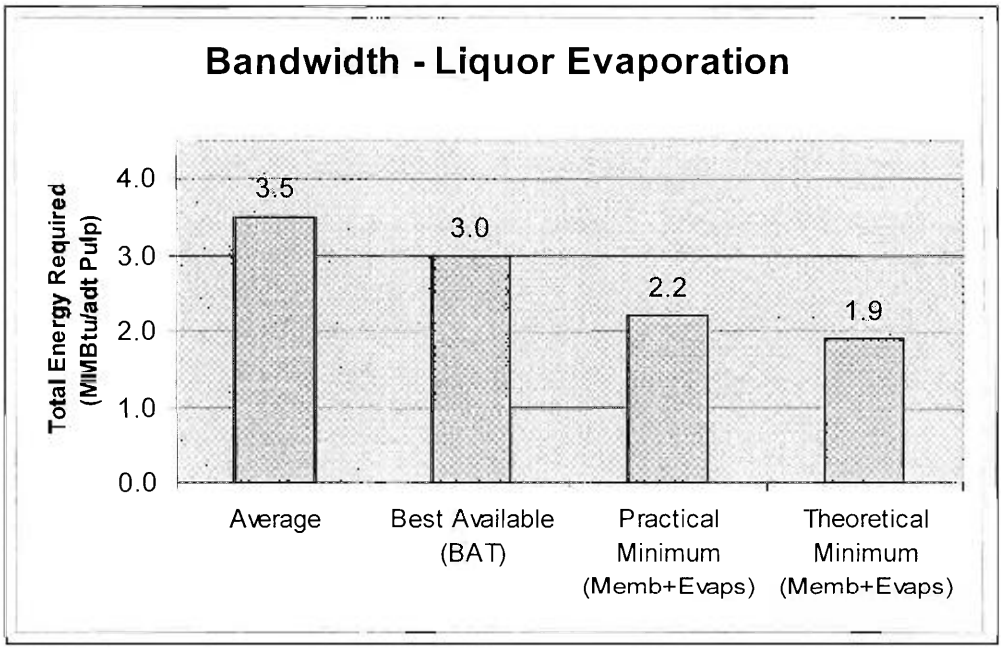
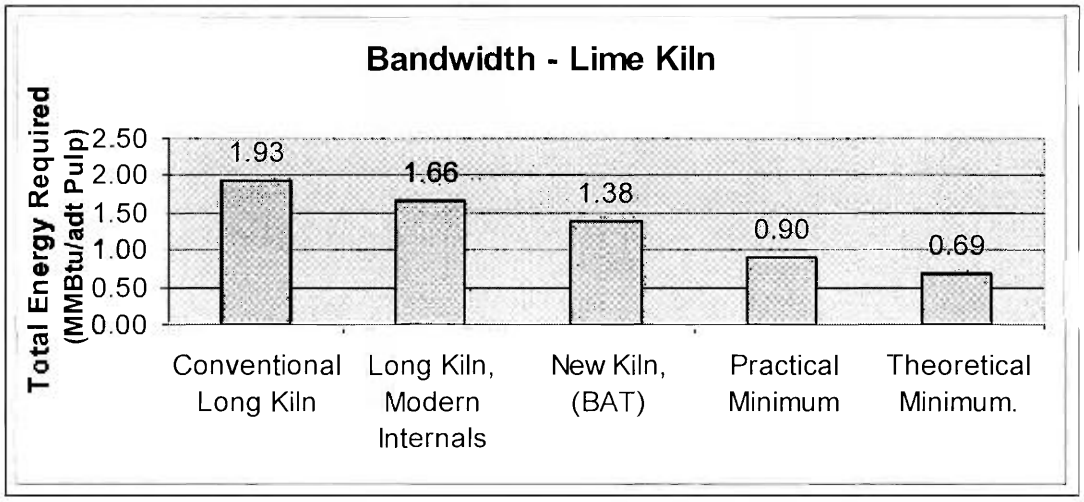


Figure 8.9



The impact on the powerhouse and purchased fuels, reduced to 260 TBtu and 189 TBtu, including electricity, by applying these three practical minimum and theoretical minimum technologies are shown in Figure 8.10 and Tables 8.7 and 8.8 respectively. Corresponding reduction in purchased energy from MECS is 77% and 83% for practical minimum and theoretical minimum. Reductions in process

demands for paper drying, evaporators and lime kilns of this order will make a pulp and paper mill much more energy self-sufficient.

Figure 8.10

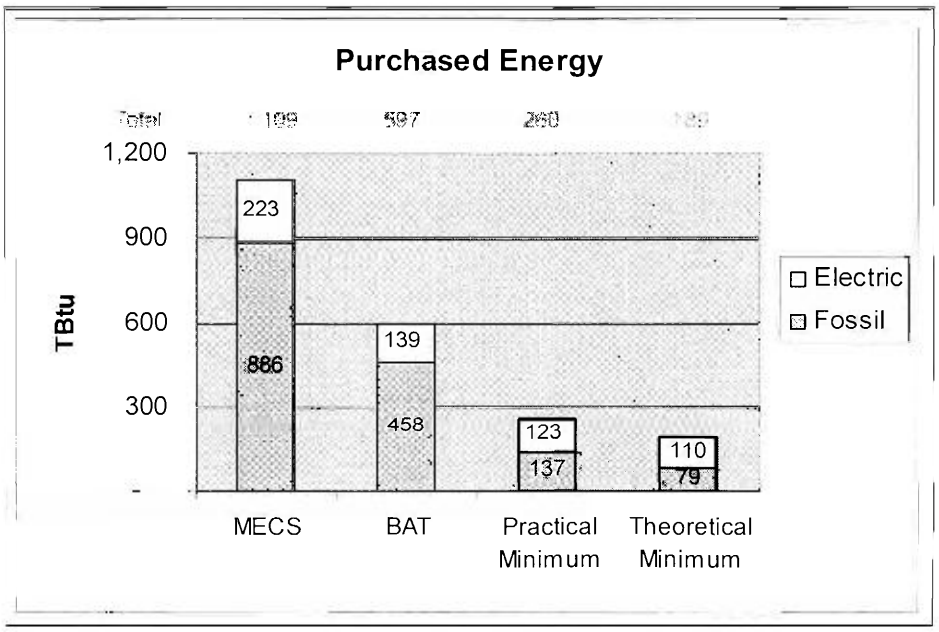


Table 8.7
Powerhouse Energy Consumption after Applying Practical Minimum

	Estimate Based on PM	Fuel Utilized In Boilers	Boiler Efficiency	Net Energy	Used for Soot Blowing Steam	Used for Boiler Aux.	Net Energy	Percent of Energy Used to Generate Electricity	Electrical Generation Conversion Loss	System & Mechanical Loss	Total Available for Process	Electricity	Electricity	Direct Fuel	Steam	% of Feed Available for Process
	TBtu	%	%	TBtu	%	%	TBtu	%	%	%	TBtu	TBtu	BkWh	TBtu	TBtu	%
Purchased Electricity	123	0%	98%	123	0%	0%	123	0%	9%	2%	120.1	120.1	35.2	-	-	98%
Coal	30	100%	88%	27	2.0%	6.0%	25	19%	9%	6%	22.7	5.8	1.7	-	16.9	75%
Residual Fuel Oil	15	100%	88%	13	0%	4.0%	13	19%	9%	6%	11.6	3.0	0.9	-	8.7	78%
Distillate Fuel Oil	2	70%	88%	2	0%	3.0%	2	0%	9%	6%	1.9	-	-	1.9	-	83%
Natural Gas	85	70%	89%	79	0%	3.0%	76	5%	9%	6%	71.3	-	-	71.3	-	84%
LPG	4	0%	88%	4	0%	0.0%	4	0%	9%	0%	3.6	-	-	3.6	-	100%
Waste Pulping Liquors	820	100%	68%	558	5.5%	4.0%	505	19%	9%	6%	465.8	119.1	34.9	-	346.8	57%
Wood / Bark	316	100%	70%	221	1.0%	5.0%	208	19%	9%	6%	191.9	49.0	14.4	-	142.9	61%
Other By Products	3	80%	70%	3	0%	4.0%	2	0%	9%	6%	2.3		-	1.8	0.5	67%
Other	0	100%	70%	0	0%	4.0%	0	3%	9%	6%	0.3	0.3	0.1	-	-	63%
Subtotal - Fuels	1,277			906			835				771	132.1	51.9	78.6	515.8	60%
Total	**1,400**			**1,029**			**957**				**891.6**	**297.3**	**87.1**	**78.6**	**515.8**	**64%**
2000 MECS	2,361			1,830			1,717				1,606	393.3	115.3	131.43	1081.4	
Difference, %	**-40.7%**			**-43.8%**			**-44.2%**				**-44.5%**	**-24.4%**	**-24.4%**	**-40.2%**	**-52.3%**	

Table 8.8
Powerhouse Energy Consumption after Applying Theoretical Minimum

	Estimate Based on TM	Fuel Utilized In Boilers	Boiler Efficiency	Net Energy	Used for Soot Blowing Steam	Used for Boiler Aux.	Net Energy	Percent of Energy Used to Generate Electricity	Electrical Generation Conversion Loss	System & Mechanical Loss	Total Available for Process	Electricity	Electricity	Direct Fuel	Steam	% of Feed Available for Process
	TBtu	%	%	TBtu	%	%	TBtu	%	%	%	TBtu	TBtu	BkWh	TBtu	TBtu	%
Purchased Electricity	110	0%	98%	110	0%	0%	110	0%	9%	2%	107.6	107.6	31.5	-	-	98%
Coal	-	100%	88%	-	2.0%	6.0%	-	19%	9%	6%	-	-	-	-	-	0%
Residual Fuel Oil	-	100%	88%	-	0%	4.0%	-	19%	9%	6%	-	-	-	-	-	0%
Distillate Fuel Oil	2	70%	88%	2	0%	3.0%	2	0%	9%	6%	1.7	-	-	1.7	-	83%
Natural Gas	74	70%	89%	68	0%	3.0%	66	5%	9%	6%	61.6	-	-	61.6	-	84%
LPG	3	0%	88%	3	0%	0.0%	3	0%	9%	0%	3.1	-	-	3.1	-	100%
Waste Pulping Liquors	820	100%	68%	557	5.5%	4.0%	504	19%	9%	6%	465.5	136.7	40.1	-	328.7	57%
Wood / Bark	316	100%	70%	221	1.0%	5.0%	208	19%	9%	6%	191.8	52.6	15.4	-	139.1	61%
Other By Products	3	80%	70%	2	0%	4.0%	2	0%	9%	6%	2.0	-	-	1.5	0.5	67%
Other	0	100%	70%	0	0%	4.0%	0	3%	9%	6%	0.3	0.3	0.1	-	-	63%
Subtotal - Fuels	1,218			854			785				726	132.1	55.6	67.8	468.3	60%
Total	**1,328**			**964**			**895**				**833.4**	**297.3**	**87.1**	**67.8**	**468.3**	**63%**
2000 MECS	2,361			1,830			1,717				1,606	393.3	115.3	131.43	1081.4	
Difference, %	**-43.8%**			**-47.3%**			**-47.9%**				**-48.1%**	**-24.4%**	**-24.4%**	**-48.4%**	**-56.7%**	

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10. APPENDIX

Appendix information is included in Tabs A thru I

- Tab A Production Figures
- Tab B Energy Consumption Reference Data
- Tab C MECS Energy Distribution
- Tab D BAT Energy Distribution
- Tab E Practical Minimum Energy Distribution
- Tab F Theoretical Minimum Energy Distribution
- Tab G Drying Calculations
- Tab H Energy Consumption Summaries
- Tab I Abbreviations

Tab A – Production

Excel Workbook: Production

			Fisher 2005 Annual Tons	Fisher Logic Annual Tons	difference		AF&PA 2002 Statistics Production 2000 (1000 tons)	AF&PA 2002 Statistics Production 2000r* (1000 tons)	AF&PA 2002 Statistics Production 2001 (1000 tons)	AF&PA 2004 Statistics Production 2002 (1000 tons)
Chemical Pulp	Sulfite	SW	581,446	578,104	3,342	all	1,169	1,169	774	532
		HW	444,034	292,152	151,882					
		total sulfite	1,025,480	870,256						
	Kraft, Unbleached	SW	18,211,369	17,506,841	704,528	all & soda	21,200	21,100	19,570	19,917
		HW	2,162,655	2,055,162	107,493					
		total kraft, unbl	20,374,024	19,562,003						
	Kraft, Bleached	SW	15,257,108	12,562,114	2,694,994		14,196	14,196	13,758	13,848
		HW	16,600,123	14,237,997	2,362,126		16,565	16,565	15,604	15,404
		total kraft, bl	31,857,231	26,800,111			30,761	30,761	29,362	29,251
	NSSC Unbleached	SW	388,630	399,969	(11,339)	all	3,955	3,955	3,527	3,547
		HW	2,369,991	2,224,149	145,842					
	Carbonate, Unbleached	SW								
		HW	1,236,700	1,095,686	141,014					
		total, Semi Chem	3,995,321	3,719,804						
	Defibrated	SW	nic 229,540				nic 292	nic 292	nic 252	
		HW	nic 401,130							
	Soda, Unbleached	Bagasse	64,000		64,000					
		Rags	4,620	4,687	(67)					
	Soda, Bleached	SW								
		HW	329,718	284,946	44,772					
		Cotton Linters	229,500	223,464	6,036					
		Rags	23,020	22,422	598					
		other	28,300	24,331	3,969					
		total soda	679,158	559,850						
Mechanical Pulp	PGW, Bleached	SW	201,615							
	SGW, Bleached	SW	682,490	855,542	28,563	all	1,924	1,924	1,627	1,416
		HW	290,405	196,443	93,962					
	SGW, Unbleached	SW	92,750	77,833	14,917					
		HW								
		total GW	1,267,260	1,129,818						
	TMP / RMP, Bleached	SW	3,663,844	3,179,873	483,971	all	3,749	3,749	3,337	3,264
		HW	200,403	151,945	48,458					
		SW, Unbleached	161,900		161,900					
	BCTMP	SW								
		HW								
		total TMP	4,026,147	3,331,818						
Recycled Pulp	Non-deinked			22,369,410	1,737,392		**62,758**	**62,658**	**58,197**	**57,928**
		OCC	19,500,502				16,973	16,973	16,446	16,683
		ONP/OMG	1,870,361							
		MOW	2,299,707				3,711	3,711	3,600	3,658
		Pulp Sub	436,222							
	Deinked			7,294,403	(245,602)					
		OCC	60,835							
		ONP/OMG	3,056,337				4,410	4,410	4,442	4,442
		MOW	3,854,245				2,347	2,347	2,063	2,021
		Pulp Sub	256,431	179,447			1,890	1,890	1,845	1,705
	Total		**94,559,261**	**85,816,920**	8,742,341		**92,088**	**92,088**	**87,085**	**86,437**

		Fisher 2005 Annual Tons	Fisher Logic Annual Tons	difference		AF&PA 2002 Statistics Production 2000 (1000 tons)	AF&PA 2002 Statistics Production 2000r* (1000 tons)	AF&PA 2002 Statistics Production 2001 (1000 tons)	AF&PA 2004 Statistics Production 2002 (1000 tons)
Paper	Corrugating Medium	12,719,160	9,875,352	2,843,808		**9,651**	**9,789**	9,317	9,806
	Linerboard	25,885,800	23,211,122	2,674,678		**20,920**	**23,484**	19,954	23,509
	Kraft Board	8,594,640	7,713,260	881,380					
	Recycled Board / Tube	7,642,080	6,701,791	940,289	tube/can	3,130	2,042	1,446	2,061
	Gypsum Board					**1,416**	**1,416**	1,448	1,429
	UnBL Folding Boxboard					4,447	5,254	6,437	4,729
	Bl Paperboard & Milk					5,437	6,484	5,297	6,346
	Coated Board								
	Other Board, unbleached					1,857	504	1,708	247
	Kraft Paper	2,272,680	1,604,957	667,723		1,707	1,707	1,601	1,545
	Bleached Pkg					329	329	290	291
	Bleached Bristols					1,487	1,487	1,297	1,350
	Uncoated Freesheet	14,809,680	13,251,789	1,557,891		13,898	13,898	12,649	12,428
	Coated Freesheet	7,121,160	5,526,991	1,594,165		4,993	4,993	4,486	4,481
	Newsprint	5,869,440	5,524,192	345,248		7,241	7,241	6,360	5,784
	Gwd Specialties	1,708,920	1,611,443	97,477		1,832	1,832	1,525	1,668
	Coated Groundwood	4,882,320	3,067,704	1,814,616		4,622	4,622	4,390	4,481
	Specialities	2,906,640	2,361,604	545,036		104	104	86	83
	Packaging & Special Industrial					2,396	2,396		2,323
	Tissue / Towel	8,172,720	7,470,609	702,111		6,911	6,911	7,024	7,127
	Tissue, TAD								
	Non-woven	nic 43920							
	Subtotal	**102,585,240**	**87,920,814**	14,664,426		**92,376**	**94,491**	**85,314**	**89,687**
					tol rep	*94,491*	*94,491*	*88,913*	*89,687*
	Kraft Pulp	11,666,520	9,588,178	2,078,342		8,013	8,013	7,916	8,153
	Kraft Pulp, unbl					292	292	247	
	Sulfite Pulp	385,920	378,770	7,150		108	108	105	
	Recycled Pulp	995,400	945,975	49,425		1,677	1,677		
	Other Pulp / dissolving	236,880	230,500	6,380		1,006	1,006	1,026	1,705
	Subtotal	**13,284,720**	**11,143,423**	2,141,297		**11,096**	**11,096**	**9,294**	**9,858**
	Total	**115,869,960**	**99,064,237**	16,805,723		**103,472**	**105,587**	**94,608**	**99,545**

2002 Statistics, Paper, Paperboard & Wood Pulp: AF&PA
Data for 2000 from 2002 Statistics
Paper shipments, p 11, capacity p 33 — Board Production by end use, p 12-13, p 22
Pulp Production, p 58, capacity p 35 — Energy p 54

2004 Statistics, Paper, Paperboard & Wood Pulp: AF&PA
Data for 2002 from 2004 Statistics
Paper shipments, p 11, capacity p 36 — Board Production by end use, p 12-18
Pulp Production, p 52, capacity p 38 — Energy - none

Pulp distribution, without Imports -- Pulp Manufactured

AF&PA 2002 Statistics, p 11 and 2004, p 11

Pulp Type	Paper Product	2002 Shipments (1000 tons)	%	% of Total	Filler %	Pulp Required	Furnish Components: NSSC	Bl Sulfite	Bl SW Kraft	Bl HW Kraft	UnBl Kraft	SGW	TMP	OCC	Non Deinked MOW	Deinked ONP
OCC, NSSC	Corrugating Medium	9,806	10.9%	9.9%	0.0%	9,806	3,547							6,259		
OCC, Unbl Kraft	Linerboard	23,509	26.2%	23.6%	0.0%	23,509					16,326			5,600	1,175	
	Recycled Board	2,061	2.3%	2.1%	0.0%	2,061								2,061		
	Gypsum Board	1,429	1.6%	1.4%	5.0%	1,357								857	500	
	Folding Boxboard	4,729	5.3%	4.8%	20.0%	3,783					2,162			1,156	411	
	Bl Folding Boxboard / Milk	6,346	7.1%	6.4%	10.0%	5,711			3,452	811						
	Other Board, unbl	247	0.3%	0.2%	0.0%	247					98			147		
OCC, Unbl Kraft	Kraft Paper	1,545	1.7%	1.6%	0.0%	1,545			368		551				480	
OCC, Unbl Kraft	Special Industrial	2,323	2.6%	2.3%	0.0%	2,323			699		780			224	350	
OCC	Newsprint	5,784	6.4%	5.8%	0.0%	5,784			62			289	1,738			3,600
OCC, OWP	Gwd Specialties	1,668	1.9%	1.7%	10.3%	1,497			187			96	290			842
OCC, OWP	Coated Groundwood	4,481	5.0%	4.5%	30.0%	3,137			571			1,031	1,237			
Bl Kraft	Bleached Pkg	291	0.3%	0.3%	0.0%	291			214							
Bl Kraft	Bleached Bristols	1,350	1.5%	1.4%	14.0%	1,161			192	712						
Bl Kraft, Bl Sulfite	Uncoated Freesheet	12,428	13.9%	12.5%	14.0%	10,688		46	772	5,063						
Bl Kraft, Bl Sulfite	Coated Freesheet	4,481	5.0%	4.5%	23.3%	3,437		55	525	1,998						
	Other Specialties	83	0.1%	0.1%	0.0%	83			43							
OCC, Unbl Kraft, Bl Kraft	Tissue / Towel	7,127	7.9%	7.2%	0.0%	7,127			1,336	2,821				378	741	
OCC, Unbl Kraft, Bl Kraft	Tissue, TAD		0.0%	0.0%	0.0%	-										
OCC, Unbl Kraft	Kraft Board		0.0%	0.0%	0.0%											
	Coated Board		0.0%	0.0%	20.0%	-										
	Non-woven		0.0%	0.0%	0.0%	-										
	Subtotal	**89,687**		**90.1%**		**83,547**	**3,547**	**101**	**8,421**	**11,404**	**19,917**	**1,416**	**3,264**	**16,683**	**3,658**	**4,442**
	Kraft Pulp	8,153	82.7%	8.2%	0.0%	8,153			4,153	4,000						
	Kraft Pulp unbl	-	0.0%	0.0%	0.0%	-			-	-	-					
	Sulfite Pulp	-	0.0%	0.0%	0.0%	-	-									
	Recycled Pulp	-	0.0%	0.0%	0.0%	-										
	Other Pulp / dissolving	1,705	17.3%	1.7%	0.0%	1,705		431	1,274							
	Subtotal	**9,858**		**9.9%**		**9,858**	-	**431**	**5,427**	**4,000**	-	-	-	-	-	-
	Total	**99,545**				**93,405**	**3,547**	**532**	**13,848**	**15,404**	**19,917**	**1,416**	**3,264**	**16,683**	**3,658**	**4,442**
		89,687			difference		0.0	0.0	0.0	(0.0)	0.0	0.0	0.0	(0.0)	(0.0)	0.0
							Total Bleached Kraft		29,251	33.8%						
							Virgin Pulp Production		57,745	66.8%		Virgin Market		9,858		

Pulp Manufactured in USA, 1000 tons

Type	2002	%	US + Imp	US + Imp - MP
Bleached Sulfite	532	0.6%	801	370
Unbleached Kraft	19,917	23.0%	20,414	20,414
Bleached Kraft Softwood	13,848	16.0%	16,858	11,431
Bleached Kraft Hardwood	15,404	17.8%	16,414	14,414
NSSC	3,547	4.1%	3,547	3,547
SGW	1,416	1.6%	1,477	1,477
TMP	3,264	3.8%	3,386	3,386
OCC	16,683	19.3%	16,683	16,683
Non deinked MOW	3,658	4.2%	3,658	3,658
Deinked MOW	2,021	2.3%	2,021	2,021
Deinked ONP	4,442	5.1%	4,442	4,442
Pulp Sub	1,705	2.0%	1,705	1,705
Subtotal	**86,437**		93,405	83,547
Virgin	57,928		64,896	55,038

		Board	48,126	53.7%
		Mechanical	11,933	13.3%
		P&W	18,259	20.4% OCC
		Recycle	28,509	33.0% 58.5%
		All Kraft		56.9%

Imported Pulp				
			SW	HW
Bleached Sulfite	269		72.7%	
Bleached Kraft	6,020		26.3%	20.9%
Semi / Unbleached Kraft	497		2.4%	
Groundwood	183		3.8%	
Subtotal	**6,968**			
Total	93,405			

Tab B – Energy Consumption

Excel Workbook: Energy Consumption Data

Energy Consumed: shown as Trillion Btus

Source	Paperloop 2004		DOE 2002 MECS		AF&PA 2000	
	TBtu	%	TBtu	%	TBtu	%
Pur Electricity	133	15.0%	**223**	**9.4%**	155	7.1%
Pur Steam	49	5.6%		0.0%	34	1.6%
Coal	187	21.1%	**236**	10.0%	266	12.2%
No 2 Oil	49	5.6%		0.0%	93	4.3%
No 6 Oil	58	6.6%		0.0%	9	0.4%
Nat Gas	407	46.1%	**504**	21.3%	396	18.2%
LPG		0.0%	**6**	0.3%	1	0.1%
Other Purchased		0.0%	**1,280**	54.2%	23	1.0%
Energy Sold		0.0%		0.0%		-2.1%
Total Purchased	**883**	**100.0%**	**2,249**	95.3%	**932**	**42.8%**
Hog		0.0%		0.0%	327	15.0%
Bl Liq		0.0%		0.0%	895	41.1%
Hydro Power		0.0%		0.0%	5	0.2%
Other		0.0%		0.0%	20	0.9%
Self Generated		**0.0%**		0.0%	**1,247**	**57.2%**
Total Energy	**883**	**100%**	**2,361**	95%	**2,179**	**100%**

Production, Mtons	79,180.4
Consumption MBtu/ton	**27.5**

Sources:
DOE 2002 - "Table 3.2, Fuel Consumption, 2002, NAICS Code 322: Paper
AF&PA 2000 - 2002 Statistics, Estimated Fuel and Energy Used, year 2000, page 55
Paperloop 2004 - Cornerstone Database

Conversions to Btu

Oil, bbl	6,200,000
Gas, mcf	1,030,000
Hog, BDst	16,000,000
Coal, st	24,000,000
Steam, 1000 lbs	1,100,000
Electricity, kWh	3,413
TDF, st	31,000,000

Published Data - Paperloop / AMEC / Jacobs Reference # 6

Energy -- Best of Class			
Area	Electric kWH/T	Steam lbs/T	Water gal/T
Woodyard	12.3		nil
TMP, Southern News	3000	(4500)	
Kraft Mill, Bleached	115	1980	475
Kraft Mill, Unbleached			
Bleach Plant, Kraft	130	710	3170
Caustic Room	40	551	
Pulp Dryer	108	2155	608
Recycle	560	nil	
Paper Mach., LWC	500	4860	4060
Paper Mach., News	580	3700	3350
Paper Mach., Liner	360	4700	5400
Paper Mach., P&W	590	6200	
Waste Water Treatment	320	na	nil

Electric		Steam			Total
Btu/kWh	MBtu/t	Assumed psi	Enthalpy Btu/lb	MBtu/t	MBtu/t
3412	0.04				0.04
3412	10.24	30	1164	(5.24)	5.00
3412	0.39	30	1164	2.30	2.70
3412	0.00			0.00	0.00
3412	0.44	75	1182	0.84	1.28
3412	0.14	75	1182	0.65	0.79
3412	0.37	150	1194	2.57	2.94
3412	1.91				1.91
3412	1.71	30	1164	5.66	7.36
3412	1.98	30	1164	4.31	6.29
3412	1.23	150	1194	5.61	6.84
3412	2.01	75	1182	7.33	9.34
3412	1.09				1.09

Kraft Market Pulp 5.90

Europe SIS Ecolabling Data, 26 Oct 2000

Area	Electric kWH/mt	Fossil GJ/mt	Water gal/mt
Kraft, market pulp	883	2.63	
Sulfite, market pulp	1465	1.62	
CTMP, market pulp	2000	1.12	
Recycled, market pulp	290	0.90	
Tissue	2165	4.93	

Electric		Fossil	Total
kWh/t	MBtu/t	MBtu/t	MBtu/t
801	2.73	2.26	4.99
1329	4.53	1.39	5.93
1814	6.19	0.96	7.15
263	0.90	0.77	1.67
1964	6.70	4.24	10.94

Table 1, page 6 - Pulp & Paper Industry Energy Best Practices, Guidebook - Wisconsin Paper Council, TAPPI, AF&PA Report by "focus on energy" Reference # 1 & 2

Gross energy per ton of saleable paper

	Market Pulp Mill		Recycled Linerboard		Fine Papers (purchased Kraft)		Coated 1-3 (purchased Kraft)		Coated 4-5 (Purchased Kraft 1/3; self produced ground wood 1/3 & filler 1/3)		Recycled Tissue	
Units	MMBtu	kWh	MMBtu	kWh	MMBtu	kWh	MMBtu	kWh	MMBtu	kWh	MMBtu	kWh
Wood/Chip Conveying	0.0	18							0.0	15		
Pulping, repulping or recycling	1.5	63	0.8	110	0.6	90	0.6	100	0.2	30	1 8	300
Mechanical Pulping (TMP)									1.3	575		
Oxygen Delignification	0.4	68										
Bleaching	2.0	91							0 1	10	0 5	50
Pulp Making	2.0	128										
Paper Making			4.0	310	3.9	410	4.5	590	4 7	600	6	581
Black Liquor Evaporation	2.7	27										
Utilities (incl wastewater)	2.0	138	0.3	30	0.3	30	0.3	30	0.4	30	0.6	30
Kiln & Recausticizing	1 0	46										
Total	11 6	579	5 1	450	4 8	530	5 4	720	6.7	1260	8.9	961

	Market Pulp Mill		Recycled Linerboard		Fine Papers (purchased Kraft)		Coated 1-3 (purchased Kraft)		Coated 4-5 (Purchased Kraft 1/3; self produced ground wood 1/3 & filler 1/3)		Recycled Tissue	
Units	Thermal MMBtu	Electric MMBtu	Thermal MMBtu	Electric MMBtu	Thermal MMBtu	Electric MMBtu	Thermal MMBtu	Electric MMBtu	Thermal MMBtu	Electric MMBtu	Thermal MMBtu	Electric MMBtu
Wood/Chip Conveying	0.00	0.06							0 00	0.05		
Pulping, repulping or recycling	1.50	0.21	0.80	0.38	0.60	0.31	0.60	0.34	0.20	0 10	1 80	1 02
Mechanical Pulping (TMP)									1.30	1.96		
Oxygen Delignification	0 40	0.23										
Bleaching	2.00	0.31							0 10	0.03	0 50	0 17
Pulp Making	2.00	0 44										
Paper Making			4 00	1.06	3.90	1 40	4 50	2.01	4 70	2.05	6 00	1 98
Black Liquor Evaporation	2.70	0.09										
Utilities (incl wastewater)	2.00	0.47	0.30	0.10	0 30	0 10	0.30	0.10	0.40	0 10	0.60	0 10
Kiln & Recausticizing	1 00	0.16										
Total	11 60	1.98	5 10	1.54	4 80	1 81	5 40	2 46	6.70	4.30	8.90	3.28
Grand Total (MMBtu)	**13.58**		**6.64**		**6.61**		**7.86**		**11.00**		**12.18**	

CIPEC / Paprican - Energy Cost Reduction in Pulp & Paper Industry
An Energy Benchmarking Perspective
Table p7. Gross energy per ton of saleable paper

	Market Pulp Mill		Newsprint		Recycled ONP		Market Pulp Mill		Newsprint		Recycled ONP	
Units	GJ/admt	kWh/admt	MMBtu/admt	kWh/admt	MMBtu/admt	kWh/admt	MMBtu/adt	kWh/adt	MMBtu/adt	kWh/adt	MMBtu/adt	kWh/adt
Wood/Chip Conveying		20.0		40.0				18.1		36.3		
Pulping, Repulping, recycling	1.7	40.0			0.8	400.0	1.46	36.3			0.69	362.8
Washing Screening	0.0	30.0		240.0				27.2		217.7		
Mechanical Pulping (TMP)				2,160.0				0.0		1,959.1		
Oxygen Delignification	0.5	75.0					0.45	68.0				
Bleaching	2.3	100.0					2.09	90.7				
Pulp Machine	2.3	141.0					2.09	127.9				
Stock Prep			0.7	100.0				0.0	0.60	90.7		
Paper Machine Forming			0.3	140.0				0.0	0.26	127.0		
Paper Drying & Finishing			3.2	90.0				0.0	2.92	81.6		
Black Liquor Evaporation	3.1	30.0					2.81	27.2				
Power Plant	2.3	60.0	0.5				2.09	54.4	0.43			
Hot Water Supply		32.0	(5.2)	10.0				29.0	(4.73)	9.1		
Wastewater Treatment		30.0						27.2				
Misc		30.0						27.2				
Kiln & Recausticizing NG	1.2	50.0					1.09	45.4				
Total	13.4	638.0	(0.6)	2,780.0	0.8	400.0	12.07	578.7	(0.52)	2,521.5	0.7	362.8
Recovery Boiler	(15.0)	(655.0)					(13.59)	(594.1)				
Net	(1.6)	(17.0)	(0.6)	2,780.0	0.8	400.0	(1.51)	(15.4)	(0.5)	2,521.5	0.7	362.8

	Market Pulp Mill		Newsprint		Recycled ONP		Market Pulp Mill		Newsprint		Recycled ONP	
Units	Thermal MMBtu	Electric MMBtu	Thermal MMBtu	Electric MMBtu	Thermal MMBtu	Electric MMBtu	Thermal MMBtu/adt	Electric MMBtu/adt	Thermal MMBtu/adt	Electric MMBtu/adt	Thermal MMBtu/adt	Electric MMBtu/adt
Wood/Chip Conveying							0.0	0.1	0.0	0.1	0.0	0.0
Pulping, repulping or recycling							1.5	0.1	0.0	0.0	0.8	1.4
Mechanical Pulping (TMP)							0.0	0.1	0.0	0.7	0.0	0.0
Oxygen Delignification							0.0	0.0	0.0	6.7	0.0	0.0
Bleaching							0.5	0.2	0.0	0.0	0.0	0.0
Pulp Making							2.1	0.3	0.0	0.0	0.0	0.0
Stock Prep							2.1	0.4	0.0	0.0	0.0	0.0
Paper Machine Forming							0.0	0.0	0.6	0.3	0.0	0.0
Paper Drying & Finishing							0.0	0.0	0.3	0.4	0.0	0.0
Black Liquor Evaporation							0.0	0.0	2.9	0.3	0.0	0.0
Utilities (incl wastewater)							2.8	0.1	0.0	0.0	0.0	0.0
Kiln & Recausticizing							2.1	0.2	0.4	0.0	0.0	0.0
Total							11.0	1.5	4.2	8.6	0.8	1.4
Grand Total (MMBtu)							**12.5**		**12.8**		**2.1**	

Energy Efficiency and the Pulp and Paper Industry, IE962 Reference #8

Table 3.2, Bleached Kraft Mill, p 32

Steam Consumption (GJ/admt)

	Bleached Kraft				
	US60	US80	M80	M00	Avg
Woodroom	0	0	0.30	0.10	0.1
Digester	4.57	2.89	2.50	1.50	2.9
Washing	0	0	0.00	0.00	0.0
Screening	0	0	0.00	0.00	0.0
O_2 Delignification	0.43	0	0.35	0.70	0.4
Bleaching	1.15	0.51	1.35	0.15	0.8
Screening & Storage	0	1.08	0.00	0.20	0.3
Recasuticizing & Kiln (ex fuel)	0.31	0	0.15	0.00	0.1
BI Evaporation	5.26	4.33	3.75	2.95	4.1
Sub Total	11.72	8.81	8.40	5.60	8.6
UnBleached	10.14	8.30	6.70	4.75	7.5
Powerhouse	2.50	3.91	0.50	0.00	1.7
Wastewater Treatment	0	0	0.00	0.00	0.0
Other	4.41	3.51	0	0	2.0
Pulp Drying & baling	5.92	3.94	3.25	2.15	3.8
Total	24.55	20.17	12.15	7.75	16.2
Other					
US60 Utilities & sootblowing	2.50				
US60 Deareation, water hating,	4.41				
US80 Deareation, water hating, chiller		3.51			

Steam, MMBtu/adt

	Bleached Kraft				
	US60	US80	M80	M00	Avg
Woodroom	0.0	0.0	0.3	0.09	0.09
Digester	3.9	2.5	2.1	1.3	2.46
Washing	0.0	0.0	0.0	0.0	0.00
Screening	0.0	0.0	0.0	0.0	0.00
O_2 Delignification	0.4	0.0	0.3	0.6	0.32
Bleaching	1.0	0.4	1.2	0.1	0.68
Screening & Storage	0.0	0.9	0.0	0.2	0.28
Recasuticizing & Kiln (ex fuel)	0.3	0.0	0.1	0.0	0.10
BI Evaporation	4.5	3.7	3.2	2.5	3.50
Sub Total	10.08	7.58	7.22	4.82	7.42
UnBleached	8.72	7.14	5.76	4.08	6.43
Powerhouse	2.1	3.4	0.4	0.0	1.49
Wastewater Treatment	0.0	0.0	0.0	0.0	0.00
Other	3.8	3.0	0.0	0.0	1.70
Pulp Drying & baling	5.1	3.4	2.8	1.8	3.28
Total	21.11	17.34	10.45	6.66	13.89
Other					
US60 Utilities & sootblowing	2.1				
US60 Deareation, water hating,	3.8				
US80 Deareation, water hating, chiller		3.0			

Electric Power Consumption (kWh/admt)

	Bleached Kraft					kWh/adt	kWh/adt
	US60	US80	M80	M00	Avg	Avg	M00
Woodroom	0	25	75	75	43.8	39.7	68
Digester	0	43	50	40	33.3	30.2	36
Washing	0	0	40	10	12.5	11.3	9
Screening	212	103	45	20	95.0	86.2	18
O_2 Delignification	0	47	60	85	48.0	43.5	77
Bleaching	185	42	120	60	101.8	92.3	54
Screening & Storage	0	74	50	40	41.0	37.2	36
Recasuticizing & Kiln (ex fuel)	141	42	35	45	65.8	59.6	41
BI Evaporation	0	66	25	30	30.3	27.4	27
Sub Total	538	442	500	405	471.3	427.4	367
UnBleached	353	400	380	345	369.5	335.1	313
					471.3	427.4	
Powerhouse	0	125	60	60	61.3	55.6	54
Wastewater Treatment	0	0	35	30	16.3	14.7	27
Other	208	61	15	35	79.8	72.3	32
Pulp Drying & baling	174	153	130	110	141.8	128.6	100
Total	920	781	740	640	770.3	699	580
Other							
US60 utilities & water plant	208				208.0	188.7	0
US80 water & air supply, HVAC, odor, etc		62			62.0	56.2	0

Electric, MMBtu/adt

	Bleached Kraft				
	US60	US80	M80	M00	Avg
Woodroom	0.00	0.08	0.23	0.23	0.14
Digester	0.00	0.13	0.15	0.12	0.10
Washing	0.00	0.00	0.12	0.03	0.04
Screening	0.66	0.32	0.14	0.06	0.29
O_2 Delignification	0.00	0.15	0.19	0.26	0.15
Bleaching	0.57	0.13	0.37	0.19	0.31
Screening & Storage	0.00	0.23	0.15	0.12	0.13
Recasuticizing & Kiln (ex fuel)	0.44	0.13	0.11	0.14	0.20
BI Evaporation	0.00	0.20	0.08	0.09	0.09
Sub Total	1.66	1.37	1.55	1.25	1.46
UnBleached	1.09	1.24	1.18	1.07	1.14
Powerhouse	0.00	0.39	0.19	0.19	0.19
Wastewater Treatment	0.00	0.00	0.11	0.09	0.05
Other	0.64	0.19	0.05	0.11	0.25
Pulp Drying & baling	0.54	0.47	0.40	0.34	0.44
Total	2.85	2.42	2.29	1.98	2.38
Other					
US60 utilities & water plant	0.64				0.64
US80 water & air supply, HVAC, odor, etc		0.19			0.19

Energy Efficiency and the Pulp and Paper Industry, IE962 Reference #8											
					page	date	MMBtu/Adt	kWh/adt			
Most Electricity: fans & pumps		40-45% / 15-20%			p20	1990					
Stock Prep and Ppaper Machine		200-300 kWh/ADMT			p 20	1989		181-272	Conversion		
Chip transport, blower vs conveyors		5 Wh/t-m horizontal conveyor			p21	86			GJ/admt	MMBtu/adt	
		5 Wh/t-m vertical conv							1	0.86	
		10 Wh/t-m	horizontal blower								
		15 Wh/t-m	vertical blower						kWh/admt	kWh/adt	
O2 Delignif		0.5 GJ/admt (0.5MMbtu/admt)			p21		0.43		1	0.9	
		75 kWh/admt						68			
Digester, conventional		3.5-4.0 GJ/admt			p22	92	3.01-3.44				
continuous / modern batch		1.7-2.5 GJ/admt					1.46-2.15				
Evap steam inc batch displacement		0.5 GJ/admt (0.5MMbtu/admt)									
Bleaching		20-30 kWh/admt			p22	93		18-27			
Pulp (Drying) Machine		130-150 kWh/admt			p23	77		118-136			
		3.3 - 3.5 GJ/admt					2.84-3.01				
Rebuilding Pulp Drying machine		171 kWh/admt to 141 kWh/admt			p23	1994		171 to 128			
		3.39 GJ/admt to 2.26 GJ/admt					2.91 to 1.94				
Lime Kiln fuel,(m00)		1.3 GJ/admt			p25		1.16				
Canadian & Swedish		2.7 GJ/admt - 1.8 GJ/admt				1989	2.32-1.55				
TMP		< 0.5 GJ/admt			p26	1989	0.43				
TMP - heat recovery - Possible		65% (4 GJ/admt)			p26		3.44				
Sweden		32% (2.7 GJ/admt)				1988	2.32				
Mechanical pulping calculated minimum		300-400 kWh/admt			p26	87		272-363			
Single disk		2200 kWh/admt						1996			
double disk		1800 kWh/admt						1633			
additional - reject refining		200-300 kWh/admt			p26	94		181-272			
Concept greenfield newsprint mill		1495 kWh/admt of paper			p26			1356			
would have excess steam / bark / methane											
TMP		1475 kWh/admt						1338			
Recycle		475 kWh/admt						431			
Drying, newsprint, (Canadian)		2.264 GJ/admt of paper			p27	1993	1.95				
Energy Savings - VS drivews over 50kW motors		30%			p29	1989					
Energy Savings, natural ventilation machine roo		eliminate 160 Kw fan			p29	1990					
Anaerobic Treatment papermill sludges		85 kWh/admt			p30	1989		77			
ESP on recovery boiler		6 kWh/admt			p30	1977		5			
SGW / PGW	newsprint	1790-2300	kWh/admt		p34			1736-2086			
	catalog	2100-2350	kWh/admt					1905-2131			
	board	800-1290	kWh/admt					726-1170			
	typical	1260-1450	kWh/admt			1988		1143-1315			
TMP	newsprint	2200-2450	kWh/admt					1995-2222			
	catalog	2080	kWh/admt					1633			
	board	1670-2170	kWh/admt					1514-1968			
	average	1800	kWh/admt			1988		1633			
	newsprint	1850-2500	kWh/admt			1994		1665-2268			
Chemi-mechanical	fluff pulp	900	kWh/admt					816			
	tissue	1400-1600	kWh/admt					1270-1451			
	P&W	2200-2400	kWh/admt					1995-2177			
Recycle	liner	260	kWh/admt					236			
	Newsprint	370	kWh/admt					336			
	other	440	kWh/admt					399			
Newsprint Mill, p 35											
	News mill, 1980-85				Newsprint Mill Model 2000						
	GJ/admt	MMBtu/adt	kWh/admt	kWh/adt	GJ/admt	MMBtu/adt	kWh/admt,	kWh/adt			
Wood prep			23	21			45	41			
TMP Pulp			1624	1473			885	803			
recycle fiber			80	73			160	145			
stock prep			75	68			30	27			
paper machine	3.36	2.89	265	240	2.23	1.92	290	263			
waste water			34	31			85	77			
Total	3.36	2.89	2101	1906	2.23	1.92	1495	1356			

The Energy Roadmap, Forest Products Association of Canada (FPAC)

Tom Browne, Paprican

Thermal Consumption, unless noted

	Minimum GJ/odmt	Maximum GJ/odmt	Median GJ/odmt	Min MMBtu/adt	Max MMBtu/adt	Median MMBtu/adt	Median BI Kraft Mill MMBtu/adt
Kraft pulping, Continuous Digester	1.50	7.00	3.00	1.43	6.69	2.87	11.39
Kraft pulping, Batch Digester	12.40	9.05	5.10	11.85	8.65	4.87	
Kraft Evaporators, No Direct Contact Concentrator	3.00	9.90	6.00	2.87	9.46	5.73	
Kraft Evaporators, Direct Contact Concentrator	2.10	30.00	2.95	2.01	28.66	2.82	
Kraft RB, Low Odor, **FUEL**	20.00	32.00	28.00	19.11	30.57	26.75	
Kraft RB, Direct Contact Concentrator, **FUEL**	18.00	37.00	26.00	17.20	35.35	24.84	
Kraft RB, Low Odor	1.00	5.90	2.50	0.96	5.64	2.39	
Kraft RB, Direct Contact Concentrator	0.90	5.60	1.90	0.86	5.35	1.82	
Kraft RB, Low Odor, Net Thermal Production	19.00	9.00	16.00	18.15	8.60	15.29	
Kraft RB, Direct Contact Concentrator, Net Thermal Production	14.00	9.00	11.00	13.38	8.60	10.51	
Kraft Causticizing, **FUEL**	1.49	3.20	2.10	1.42	3.06	2.01	
Kraft Causticizing	0.00	1.22	0.20	0.00	1.17	0.19	
Kraft Bleaching	1.00	6.60	3.20	0.96	6.31	3.06	
Mechanical Pulping / TMP	0.00	3.30	0.60	0.00	3.15	0.57	
Mechanical Pulping / TMP, **Assumed SGW**	1.00	3.30	1.50	0.96	3.15	1.43	
Mechanical Pulping / TMP, Production	4.00	0.00	0.00	3.82	0.00	0.00	
Mechanical Pulping / **Assumed TMP**, Production	4.00	1.40	3.50	3.82	1.34	3.34	
Mechanical Pulping / TMP, Net Production	4.00			3.82			
Paper Machine, Newsprint	3.70	11.00	5.30	3.53	10.51	5.06	
Paper Machine, Uncoated Groundwood Specialties	3.80	8.10	6.10	3.63	7.74	5.83	
Paper Machine, Printing & Writing	4.10	11.50	6.10	3.92	10.99	5.83	
Pulp Machine, Steam Dryer	3.50	6.40	4.50	3.34	6.11	4.30	
Deink / Recycle			2.00			1.91	

	Minimum Electric kWh/odmt	Maximum Electric kWh/odmt	Median Electric kWh/odmt	Minimum Electric kWh/adt	Maximum Electric kWh/adt	Median Electric kWh/adt	Minimum Electric MMBtu/adt	Maximum Electric MMBtu/adt	Median Electric MMBtu/adt
Mechanical Pulping / TMP	2100	3900	2700	2116	3930	2721	2006	3726	2580
Deink / Recycle			500			504			478
Paper & Pulp Machines			500			504			478
TMP Newsprint, (Benchmarking)	2400	3000	2800	2419	3023	2822	2293	2866	2675

Energy Use Handbook, Canada, p 56

	1998 mJ/odmt	1999 mJ/odmt	2000 mJ/odmt	2001 mJ/odmt	1998 MMBtu/adt	1999 MMBtu/adt	2000 MMBtu/adt	2001 MMBtu/adt
Pulp Mills	36,772	36,382	35,196	37,402	35.13	34.76	33.62	35.73
Paper Mills, except Newsprint	17,437	16,932	16,276	14,905	16.66	16.18	15.55	14.24
Newsprint Mills	31,877	33,189	32,588	31,361	30.45	31.71	31.13	29.96
Paperboard Mills	19,392	17,801	16,989	16,837	18.53	17.01	16.23	16.09

Benchmarking Energy use in Pulp & paper industry, Francis, Towers, Browne Reference #13

Bleached Kraft Market Pulp

	Electricity kWh/odmt	Fuel GJ/odmt	Thermal GJ/odmt	Thermal Production GJ/odmt	Net Thermal Production GJ/odmt	Electricity kWh/adt	Fuel MMBtu/adt	Thermal MMBtu/adt	Thermal Production MMBtu/adt	Net Thermal Production MMBtu/adt
25 Percentile	565.1	25.7	16.46	14.75	0.9	540	24.55	15.73	14.09	0.86
Median	656.2	29.45	19.06	16.36	3.48	627	28.14	18.21	15.63	3.32
75 Percentile	713.1	30.59	21.25	17.49	4.67	681	29.22	20.31	16.71	4.46
Modern	511		10.9			488	0.00	10.41	0.00	0.00

Newsprint

	Electricity kWh/odmt	Fuel GJ/odmt	Thermal GJ/odmt	Thermal Production GJ/odmt	Net Thermal Production GJ/odmt	Electricity kWh/adt	Fuel MMBtu/adt	Thermal MMBtu/adt	Thermal Production MMBtu/adt	Net Thermal Production MMBtu/adt
25 Percentile	2779.3	0	5.54	0	2.63	2655	0.00	5.29	0.00	2.51
Median	2908.5	0	6.1	2.81	5.31	2779	0.00	5.83	2.68	5.07
75 Percentile	2970.1	0	6.8	3.33	5.95	2838	0.00	6.50	3.18	5.68
Modern, Avg.	2690.0	0	4.9	4.9	0	2570	0.00	4.68	4.68	0.00

The Energy Roadmap, Forest Products Association of Canada (FPAC)

Thermal Consumption, Table IV	25 Percentile GJ/odmt	Median GJ/odmt	75 Percentile GJ/odmt	Modern GJ/odmt	25 Percentile MMBtu/adt	Median MMBtu/adt	75 Percentile MMBtu/adt	Modern MMBtu/adt	Median Bl. Kraft Mill MMBtu/adt	Avg. - Modern & 25% Perc.	Avg - 25% & Modern Kraft MMBtu/adt
Kraft pulping Continuous	1.48	2.43	2.94	2.2	1.41	2.32	2.81	2.10	10.49	2.39	7.13
Kraft Pulping, Batch	2.84	4.33	4.94	3.5	2.71	4.14	4.72	3.34			
Kraft Pulping, M&D	4.8	5.5	6.04	na	4.59	5.25	5.77				
Kraft Evaporators, Indirect Contact	3.07	5.03	5.91	3.2	2.93	4.81	5.65	3.06		3.00	
Kraft Evaporators, Direct Contact	2.28	2.9	2.96	na	2.18	2.77	2.83				
Kraft Bleaching, Softwood	1.95	2.57	2.33	1.7	1.86	2.46	2.23	1.62		1.74	
Kraft Bleaching, Hardwood	1.02	1.62	2.33	na	0.97	1.55	2.23				
Kraft Pulping, Recausticizing, FUEL (table VI)	1.96	2.15	2.34	1.7	1.87	2.05	2.24	1.62		1.75	
Mechanical Pulping, TMP for News	0.04	0.39	0.56	0	0.04	0.37	0.54	0.00		0.02	
Mechanical Pulping, TMP for Paper	0	0.03	0.67	0	0.00	0.03	0.64	0.00		0.00	
Paper Machine, Newsprint	4.77	5.36	6.62	4.9	4.56	5.12	6.32	4.68		4.62	
Paper Machine, Uncoated Groundwood	4.93	6.21	7.01	na	4.71	5.93	6.70				
Paper Machine, Printing & Writing	5.74	6.32	8.31	5.1	5.48	6.04	7.94	4.87		5.18	
Paper Machine, Kraft papers	8.47	9.1	9.11	na	8.09	8.69	8.70				
Paper Machine, Board	6.92	6.94	7.18	3.4	6.61	6.63	6.86	3.25		4.93	
Pulp Machine, Dryer	4.14	4.59	5.26	2.3	3.96	4.39	5.03	2.20		3.08	
Table VII - Thermal Energy Consumption of Boilers											
Power Boilers	0	0.02	0.06	0	0.00	0.02	0.06	0.00			
Recovery Boiler, low Odor	0.11	0.14	0.19	0.05	0.11	0.13	0.18	0.05			
Recovery Boiler, Direct Contact	0.14	0.16	0.17	na	0.13	0.15	0.16				

Energy Cost Reduction in the Pulp and Paper Industry, Paprican, Nov 1999 Reference #12

Table 5.2, page 79 Bleached Kraft Mill

	Steam GJ/admt	Electric kWh/admt	Electric kWh/adt	Steam MMBtu/adt	Electric MMBtu/adt	Total MMBtu/adt
1988 Avg Us	15.2	840	762	13.1	2.6	15.7
1988 Best Swedish	12.4	720	653	10.7	2.2	12.9
2000 Model	7.8	640	580	6.7	2.0	8.7

Table 5.3, p 80, Steam Consumption (GJ/admt)

	Softwood					Hardwood		Steam, MMBtu/adt	Softwood			
	1990 SA	1990 SA	1990 NA	1990 Europe	Model	1990 NA	1990 Europe	1990 SA	1990 SA	1990 NA	1990 Europe	Avg
Woodroom	0	0	0.00	0.20	0.00	0.38	0.40	0.00	0.00	0.00	0.17	**0.04**
Digester, Washing, Screening	2.34	2	3.33	3.20	1.79	1.94	2.20	2.01	1.72	2.86	2.75	**2.34**
O_2 Delignification	1.32	0.5	0.18	0.20	0.40	0.31	0.00	1.13	0.43	0.15	0.17	**0.47**
Bleaching	2.84	0.4	0.58	0.40	0.00	3.38	2.63	2.44	0.34	0.50	0.34	**0.91**
Chem Prep	0.31	0.4	0.37	0.30	0.11	0.17	0.30	0.27	0.34	0.32	0.26	**0.30**
Recausticizing & Kiln	0.4	0.3	0.00		0.00	0.00	0.30	0.34	0.26	0.00	0.00	**0.15**
Evaporation & Stripping	3.9	4.2	5.40	4.20	3.34	3.77	3.04	3.35	3.61	4.64	3.61	**3.80**
Sub Total	**11.11**	**7.80**	**9.86**	**8.50**	**5.64**	**9.95**	**8.87**	9.55	6.71	8.48	7.31	**8.01**
UnBleached	**6.95**	**6.90**	**9.10**	7.90	**5.24**	**6.26**	**6.24**	5.98	5.93	7.82	6.79	**6.63**
Steam & Chemical Recovery	3.28	1.7	2.61	1.60	1.22	1.05	0.92	2.82	1.46	2.24	1.38	**1.98**
Pulp Drying	2.69	2.7	4.49	3.10	2.32	4.13	2.98	2.31	2.32	3.86	2.67	**2.79**
Total	**17.09**	**12.2**	**16.96**	**13.20**	**9.18**	**15.12**	**10.77**	**16.2**	**11.6**	**16.1**	12.5	**14.1**

Table 5.4, p 80, Electric Power Consumption (kWh/admt)

	Softwood					SW	Hardwood			Electric, MMBtu/adt	Softwood		
	1990 NA	1990 NA	1990 Chile	1990 Europe	Avg kWh/adt	Model	1990 NA	1990 Europe	Avg kWh/adt	1990 NA	1990 NA	1990 Chile	1990 Europe
Woodroom	24	43	37	20	**28**	55	68	28	**44**	20.6	37.0	31.8	17.2
Digester, Washing, Screening	168	181	180	205	**166**	125	156	156	**141**	144.5	155.6	154.8	176.3
O_2 Delignification	inc above	inc above	inc above	inc above		inc above	inc above	inc above		inc above	inc above	inc above	inc above
Bleaching	124	33	132	110	**90**	55	92	94	**84**	106.6	28.4	113.5	94.6
Chem Prep											0.0	0.0	0.0
Recausticizing & Kiln	30	61	23	25	**32**	60	14	19	**15**	25.8	52.4	19.8	21.5
Evaporation & Stripping	125	75	98	30	**74**	35	125	28	**69**	107.5	64.5	84.3	25.8
Sub Total	**471**	**393**	**470**	**390**	**391**	**330**	**455**	**325**	**354**	**405.0**	**337.9**	**404.1**	**335.3**
UnBleached	**347**	**360**	**338**	**280**	**300**	**275**	**363**	**231**	**269**	**298.4**	**309.5**	**290.6**	**240.8**
Steam & Chemical Recovery	191	18	124	110	**100**	90	91	150	**109**	164.2	15.5	106.6	94.6
Wastewater Treatment	68	108	56	40		40	85	45	**59**	58.5	92.9	48.2	34.4
Pulp Drying	155	150	143	140	**133**	165	114	122	**107**	133.3	129.0	123.0	120.4
Total	**885**	**669**	**793**	**680**	**686**	**625**	**745**	**642**	**629**	761.0	575.2	681.8	584.7

Energy Cost Reduction in the Pulp and Paper Industry, Paprican, Nov 1999 Reference #12

Table 7.1, page 120 Range of Energy Consumption

	Steam GJ/mt			Gas GJ/mt	Electric kWh/mt			Electric kWh/adt	Electric kWh/adt	Steam MMBtu/t			Gas MMBtu/t
	Min	Max	Avg	Avg	Min	Max	Avg	Avg	Min	Min	Max	Avg	Avg
Newsprint	3.4	5.5	4.5		420	630	525	476	381	2.9	4.7	3.8	
Coated groundwood	5.1	5.6	5.4		550	820	685	621	499	4.4	4.8	4.6	
Uncoated woodfree	4.3	7.2	5.8		550	670	610	553	499	3.7	6.2	4.9	
Coated woodfree	3.7	7.7	5.7		440	900	670	608	399	3.2	6.6	4.9	
Linerboard	3.4	8.8	6.1		515	660	588	533	467	2.9	7.6	5.2	
Tissue	2.6	4.5	3.6	2.2	835	1050	943	855	757	2.2	3.9	3.1	1.9
Average	3.8	6.6	5.2	2.2	552	788	670	608	500	3.2	5.6	4.4	1.9

Table 7.2, page 120 Typical Energy Consumption - Newsprint

	Steam GJ/admt	Electric kWh/admt	Electric kWh/adt	Steam MMBtu/adt	Electric MMBtu/adt	Total MMBtu/adt
Stock Preparation	0.66	100	91	0.6	0.3	0.9
Forming & Pressing	0.3	142	129	0.3	0.4	0.7
Drying & Finishing	3.2	45	41	2.8	0.1	2.9
Auxiliary systems	0	42	38	0.0	0.1	0.1
Total	4.16	329	298	3.6	1.0	4.6

Energy required for Lime Kilns. P 89

	GJ/admt Paper	MMBtu/adt Paper
Theoretical	0.77	0.66
82 Canadian survey	2.69	2.31
Modern Design	1.55	1.33

	GJ/t Lime	MMBtu/t Lime	MMBtu/t pu
Theoretical	2.88	2.48	0.66
82 Canadian survey	10.1	8.68	2.32
Modern Design	5.8	4.99	1.33

Table 8.1, page 148 Gross Energy Consumption

	Steam kWh/admt	Electric kWh/admt	Electric kWh/adt	Steam MMBtu/adt	Electric MMBtu/adt	Total MMBtu/adt
Kraft	2500	560	508	7.7	1.7	9.5
TMP/CTMP	200	3000	2721	0.6	9.3	9.9
Deinked pulp	220	600	544	0.7	1.9	2.5

Table 8.4, page 151 Typical power required for recycling and deinking

	Electric kWh/admt			Electric kWh/adt	Electric kWh/adt	Electric MMBtu/adt		
	Min	Max	Avg	Avg	Min	Min	Max	Avg
OCC to linerboard & medium	300	600	450	408	272	0.9	1.9	1.4
ONP/OMG to newsprint	500	800	650	590	454	1.5	2.5	2.0
MOW to P&W	600	1000	800	726	544	1.9	3.1	2.5
MOW to tissue	700	800	750	680	635	2.2	2.5	2.3

Table 8.2, p 148, Recycling processes

	Steam kWh/admt	Electric kWh/admt	Avg. Steam kWh/admt	Avg Electric kWh/admt	Min Electric kWh/adt	Avg. Electric kWh/adt	Avg Steam MMBtu/adt	Avg Electric MMBtu/adt	Avg. Total MMBtu/adt
Pulping	0-400	62-74	200	68	56	62	0.6	0.2	0.8
Coarse Screening		25-40		33	23	30	0.0	0.1	0.1
Flotation		38-90		64	34	58	0.0	0.2	0.2
Lightweight Cleaning		15-29		22	14	20	0.0	0.1	0.1
Heavyweight Cleaning		27-40		33.5	24	30	0.0	0.1	0.1
Fine Screening		31-69		50	28	45	0.0	0.2	0.2
Washing / Thickening / Kneading / Dispersing		17-19		18	15	16	0.0	0.1	0.1
Bleaching	0-535	30-100	267.5	65	27	59	0.8	0.2	1.0
Total					222	321	1.4		2.5

Tab C – MECS Energy Distribution

Excel Workbook: MECS Energy Distribution

See DOE Web site for Excel Workbook

Tab D – BAT Energy Distribution

Excel Workbook: BAT Energy Distribution

See DOE Web site for Excel Workbook

Tab E – Practical Minimum Energy Distribution

Excel Workbook: Pract Min Energy Distribution

See DOE Web site for Excel Workbook

Tab F – Theoretical Minimum Energy Distribution

Excel Workbook: Theor Min Energy Distribution

See DOE Web site for Excel Workbook

Tab G – Drying Calculations

Excel Workbook: Drying Calculations

TABLE A
MINIMUM THEORETICAL DRYING ENERGY
(42% Exiting Press Solids)

sheet temperature	50	C		**Notes:**
evaporation temperature	100	C		Assumes no energy needed for:
heat of evaporation at 70 C	2333	kJ/kg		•heating supply air
steam temperature in dryer can	120	C		•heating leakage air
heat of condensation at 120 C	2203	kJ/kg		•heat leakage through hood walls and roof
specific heat of water	4.18	kJ/kg/C		
specific heat of fiber	1.25	kJ/kg/C		
moisture ratio of entering sheet	1.38	kg water/kg fiber		
moisture ratio of exiting sheet	0.05	kg water/kg fiber		
heat of sorption	175	kJ/kg		
moisture ratio @ start of desorption	0.3	kg water/kg fiber		
moisture ratio @ end of desorption	0.05	kg water/kg fiber		
energy to heat water	288.4	kJ/kg fiber	mass of all water x specific heat x temperature change	
energy to heat fiber	62.5	kJ/kg fiber	mass of fiber x specific heat x temperature change	
energy to evaporate water	3103	kJ/kg fiber	mass of evaporated water x heat of vaporization	
energy to desorb water	44	kJ/kg fiber	mass of desorbed water x heat of sorption	
total energy required	3498	kJ/kg fiber		
total energy required	**2.86**	**MMBTU/FST paper**		
kJ energy req'd / kJ steam condensed	1.19	kJ/kJ	total energy / (heat of condensation x mass evaporated water)	

TABLE B
MINIMUM THEORETICAL DRYING ENERGY
(50% Exiting Press Solids)

sheet temperature	50	C		
evaporation temperture	100	C		**Notes:**
heat of evaporation at 70 C	2333	kJ/kg		Assumes no energy needed for:
steam temperature in dryer can	120	C		•heating supply air
heat of condensation at 120 C	2203	kJ/kg		•heating leakage air
specific heat of water	4.18	kJ/kg/C		•heat leakage through hood walls and roof
specific heat of fiber	1.25	kJ/kg/C		
moisture ratio of entering sheet	1	kg water/kg fiber		
moisture ratio of exiting sheet	0.05	kg water/kg fiber		
heat of sorption	175	kJ/kg		
moisture ratio @ start of desorption	0.3	kg water/kg fiber		
moisture ratio @ end of desorption	0.05	kg water/kg fiber		
energy to heat water	209	kJ/kg fiber	mass of all water x specific heat x temperature change	
energy to heat fiber	62.5	kJ/kg fiber	mass of fiber x specific heat x temperature change	
energy to evaporate water	2216	kJ/kg fiber	mass of evaporated water x heat of vaporization	
energy to desorb water	44	kJ/kg fiber	mass of desorbed water x heat of sorption	
total energy required	2532	kJ/kg fiber		
total energy required	**2.07**	**MMBTU/FST paper**		
kJ energy req'd / kJ steam condensed	1.21	kJ/kJ	total energy / (heat of condensation x mass evaporated water)	

TABLE C
MINIMUM THEORETICAL DRYING ENERGY
(70% Exiting Press Solids)

sheet temperature	50	C	
evaporation temperature	100	C	**Notes:**
heat of evaporation at 70 C	2333	kJ/kg	Assumes no energy needed for
steam temperature in dryer can	120	C	•heating supply air
heat of condensation at 120 C	2203	kJ/kg	•heating leakage air
specific heat of water	4.18	kJ/kg/C	•heat leakage through hood walls and roof
specific heat of fiber	1.25	kJ/kg/C	
moisture ratio of entering sheet	0.4286	kg water/kg fiber	
moisture ratio of exiting sheet	0.05	kg water/kg fiber	
heat of sorption	175	kJ/kg	
moisture ratio @ start of desorption	0.3	kg water/kg fiber	
moisture ratio @ end of desorption	0.05	kg water/kg fiber	
energy to heat water	89.6	kJ/kg fiber	mass of all water **x** specific heat **x** temperature change
energy to heat fiber	62.5	kJ/kg fiber	mass of fiber **x** specific heat **x** temperature change
energy to evaporate water	883	kJ/kg fiber	mass of evaporated water **x** heat of vaporization
energy to desorb water	44	kJ/kg fiber	mass of desorbed water **x** heat of sorption
total energy required	1079	kJ/kg fiber	
total energy required	**0.88**	**MMBTU/FST paper**	
kJ energy req'd / kJ steam condensed	1.29	kJ/kJ	total energy / (heat of condensation **x** mass evaporated water)

Tab H – Energy Consumption Summaries

MECS Steam		detail in MMBtu/ton								Steam TBtu		Steam TBtu	Steam MMBtu/ton
CHEMICAL PULP	Prodn (Kton/yr)	Wood Prep	Cooking	Screening / Cleaning	Washing	Evap	Lime Kiln / Chem P	Bleaching	Other				
Subt Area (kton, TBtu)	53,248	13.3	130.1	-	-	186.0	30.3	56.0	-	415.7	TBtu		7.8
Sulfite	532	0.25	2.85			2.20	0.60	2.10				4.3	8.0
Kraft, UnBleached	19,917	0.25	2.51			3.50	0.58					136.3	6.8
Kraft, Bleached, SW	13,848	0.25	2.52			3.55	0.57	1.85				121.0	8.7
Kraft, Bleached, HW	15,404	0.25	2.32			3.50	0.56	1.90				131.4	8.5
NSSC, SemiChem	3,547	0.25	2.24			3.40	0.53					22.8	6.4
MECHANICAL PULP		Wood Prep	Grinding / Refining	Screening / Cleaning	Bleaching	Other							
Subt Area (kton, TBtu)	4,680	1.1	(3.0)	-	8.8	-				6.9	TBtu		1.5
SGW	1,416	0.25	1.31		1.60							4.5	3.2
TMP	3,264	0.23	(1.50)		2.01							2.4	0.7
RECYCLED PULP				Recycling									
Subt Area (kton TBtu)	28,509			28.7						26.7	TBtu		0.9
OCC	16,683			0.84								14.0	0.8
MOW, non deinked (tissue)	3,658			0.84								3.1	0.8
ONP, deinked	4,442			1.47								6.5	1.5
MOW, deinked	2,021			1.47								3.0	1.5
Pulp Sub	1,705			-								-	-
Subtotal	86,437									449.2		449.2	5.2
PAPER MACHINE		Wet End	Pressing	Dryers, drying	Dry End / Calender		Coating, Prep	Super Cal, heat					
Subt Area (kton, TBtu)	99,545	107.8	-	422.3	-		2.5	5.3		537.8	TBtu		5.4
Corrugating Medium	9,806	1.50		4.50								58.8	6.0
Linerboard	23,509	1.50		4.61								143.6	6.1
Recycled Board	2,061	1.50		4.61								12.6	6.1
Folding Boxboard	4,728	1.20		4.56			0.10	0.25				28.9	6.1
Gypsum Board	1,429	1.50		4.61								8.7	6.1
Bl. Folding Boxboard / Milk	6,346	1.20		4.56			0.10	0.25				38.8	6.1
Other Board, unbl	247	1.30		4.14			0.10	0.25				1.4	5.8
Kraft Paper	1,545	1.16		4.32								8.5	5.5
Special Industrial	2,323	1.15		4.32								12.7	5.5
Unctd Free, Brist, & Bl Pkg	14,069	1.25		4.50								80.9	5.7
Coated Freesheet	4,481	1.25		4.09			0.10	0.25				25.5	5.7
Newsprint	5,784	0.86		3.77								26.8	4.6
Gwd Specialties	1,668	0.86		3.77								7.7	4.6
Coated Groundwood	4,481	0.66		3.79			0.20	0.30				22.2	4.9
Tissue / Towel	7,127	0.26		3.95								30.0	4.2
Other Specialties	83	1.10		4.69								0.5	5.8
Market Pulp	9,858			3.07								30.3	3.1
Subtotal	99,545									537.8		537.8	5.4
Wastewater (WWT)	99,545	0.55								54.6		54.6	0.5
Other Utilities	99,545	0.40								39.8		39.8	0.4
Subtotal	99,545									94.4		94.4	0.9
Total	99,545									1,081.4		1,081.4	10.9

MECS Electricity		detail in kWh/ton								Electric TBtu	Electric TBtu	Electric MMBtu/ton
CHEMICAL PULP	Prodn (Kton/yr)	Wood Prep	Cooking	Screening / Cleaning	Washing	Evap	Lime Kiln / Chem P	Bleaching	Other			
Subt Area (kton, TBtu)	53,248	16.4	18.9	11.5	-	8.7	9.4	13.7	-	78.6	TBtu	1.5
Sulfite	532	90.0	148.6			50.7		145.0			0.8	1.5
Kraft, UnBleached	19,917	90.0	84.5	70.0		55.0	72.8				25.3	1.3
Kraft, Bleached, SW	13,848	90.0	90.0	76.0		46.1	40.0	141.9			22.9	1.7
Kraft, Bleached, HW	15,404	90.0	80.0	60.0		40.0	35.7	128.6			22.8	1.5
NSSC, SemiChem	3,547	90.0	369.6			45.0	60.0				6.8	1.9
MECHANICAL PULP		Wood Prep	Grinding / Refining	Screening / Cleaning	Bleaching	Other						
Subt Area (kton, TBtu)	4,680	1.4	36.8	1.6	1.9	-				41.8	TBtu	8.9
SGW	1,416	90.0	1,973.3	100.0	120.0						11.0	7.8
TMP	3,264	90.0	2,451.1	100.0	120.0						30.7	9.4
RECYCLED PULP				Recycling								
Subt Area (kton, TBtu)	28,509			38.2						38.2	TBtu	1.3
OCC	16,683			372.3							21.2	1.3
MOW, non deinked (tissue)	3,658			434.3							5.4	1.5
ONP, deinked	4,442			465.4							7.1	1.6
MOW, deinked	2,021			558.4							3.9	1.9
Pulp Sub	1,705			111.7							0.6	0.4
Subtotal	86,437									158.6	158.6	1.8
PAPER MACHINE		Wet End	Pressing	Dryers, drying	Dry End / Calender		Coating, Prep	Super Cal, drive				
Subt Area (kton, TBtu)	99,545	103.2	36.5	45.0	18.4		1.2	2.7		206.9	TBtu	2.1
Corrugating Medium	9,806	331.6	110.0	116.8							18.7	1.9
Linerboard	23,509	370.0	140.0	127.5	76.0						57.2	2.4
Recycled Board	2,061	339.6	120.0	90.9	70.0						4.4	2.1
Folding Boxboard	4,728	335.0	110.0	104.1	70.0		10.0	10.0			10.3	2.2
Gypsum Board	1,429	350.0	110.0	90.5	70.0						3.0	2.1
Bl. Folding Boxboard / Milk	6,346	357.5	115.0	90.0	80.0		10.0	30.0			14.8	2.3
Other Board, unbl	247	335.0	110.0	91.5	75.0		10.0	30.0			0.5	2.2
Kraft Paper	1,545	358.5	110.0	103.0	80.0						3.4	2.2
Special Industrial	2,323	358.5	110.0	103.0	80.0						5.2	2.2
Unctd Free, Brist, & Bl Pkg	14,069	345.0	115.0	105.3	80.0						31.0	2.2
Coated Freesheet	4,481	330.0	115.0	112.4	77.3		25.0	60.0			11.0	2.5
Newsprint	5,784	300.0	105.0	87.0	66.4						11.0	1.9
Gwd Specialties	1,668	300.0	105.0	87.0	66.4						3.2	1.9
Coated Groundwood	4,481	300.0	100.0	86.0	50.0		25.0	59.6			9.5	2.1
Tissue / Towel	7,127	200.0	64.6	480.0							18.1	2.5
Other Specialties	83	358.5	105.0	108.0	80.0						0.2	2.2
Market Pulp	9,858	40.0	40.0	80.0							5.4	0.5
Subtotal	99,545									206.9	206.9	2.1
Wastewater (WWT)	99,545	36.9								12.5	12.5	0.1
Other Utilities	99,545	45.0								15.3	15.3	0.2
Subtotal	99,545									27.8	27.8	0.3
Total	99,545									393.3	393.3	4.0

MECS Direct Fuel

		detail in MMBtu/ton								Dr Fuel TBtu	Dr Fuel TBtu	Dr Fuel MMBtu/ton
CHEMICAL PULP	Prodn (Kton/yr)	Wood Prep	Cooking	Screening / Cleaning	Washing	Evap	Lime Kiln / Chem P	Bleaching	Other			
Subt Area (kton, TBtu)	53,248	-	-	-	-	-	100.2	-	-	100.2	TBtu	1.9
Sulfite	532						1.78				0.9	1.8
Kraft, UnBleached	19,917						1.87				37.3	1.9
Kraft, Bleached, SW	13,848						1.97				27.3	2.0
Kraft, Bleached, HW	15,404						1.97				30.4	2.0
NSSC, SemiChem	3,547						1.17				4.2	1.2
MECHANICAL PULP		Wood Prep	Grinding / Refining	Screening / Cleaning	Bleaching	Other						
Subt Area (kton, TBtu)	4,680	-	-	-	-	-				-	TBtu	-
SGW	1,416										-	-
TMP	3,264										-	-
RECYCLED PULP				Recycling								
Subt Area (kton, TBtu)	28,509			-						-	TBtu	-
OCC	16,683										-	-
MOW, non deinked (tissue)	3,658										-	-
ONP, deinked	4,442										-	-
MOW, deinked	2,021										-	-
Pulp Sub	1,705										-	-
Subtotal	86,437									100.2	100.2	1.2
PAPER MACHINE		Wet End	Pressing	Dryers, drying	Dry End / Calender		Coating, Drying	Super Cal, heat				
Subt Area (kton, TBtu)	99,545	-	-	13.4	-		17.9	-		31.3	TBtu	0.3
Corrugating Medium	9,806										-	-
Linerboard	23,509										-	-
Recycled Board	2,061										-	-
Folding Boxboard	4,728			-			0.9				4.2	0.9
Gypsum Board	1,429										-	-
Bl. Folding Boxboard / Milk	6,346						0.9				5.6	0.9
Other Board, unbl	247						0.5				0.1	0.5
Kraft Paper	1,545										-	-
Special Industrial	2,323										-	-
Unctd Free, Brist, & Bl Pkg	14,069										-	-
Coated Freesheet	4,481			-			0.9				4.0	0.9
Newsprint	5,784										-	-
Gwd Specialties	1,668			-							-	-
Coated Groundwood	4,481			-			0.9				4.0	0.9
Tissue / Towel	7,127			1.9							13.4	1.9
Other Specialties	83										-	-
Market Pulp	9,858										-	-
Subtotal	99,545									31.3	31.3	0.3
Wastewater (WWT)	99,545									-	-	-
Other Utilities	99,545									-	-	-
Subtotal	99,545									-	-	-
Total	99,545									131.4	131.4	1.3

MECS Stm + Elec + D Fuel

		detail in MMBtu/ton								All TBtu		All TBtu	All MMBtu/ton
CHEMICAL PULP	Prodn (Kton/yr)	Wood Prep	Cooking	Screening / Cleaning	Washing	Evap	Lime Kiln / Chem P	Bleaching	Other				
Subt Area (kton, TBtu)	53,248	29.7	149.0	11.5	-	194.7	139.9	69.7	-	594.5	TBtu		11.2
Sulfite	532	0.56	3.36	-	-	2.37	2.38	2.60	-			6.0	11.3
Kraft, UnBleached	19,917	0.56	2.80	0.24	-	3.69	2.70	-	-			198.9	10.0
Kraft, Bleached, SW	13,848	0.56	2.83	0.26	-	3.71	2.68	2.33	-			171.2	12.4
Kraft, Bleached, HW	15,404	0.56	2.59	0.20	-	3.64	2.65	2.34	-			184.6	12.0
NSSC, SemiChem	3,547	0.56	3.50	-	-	3.55	1.91	-	-			33.8	9.5
MECHANICAL PULP		Wood Prep	Grinding / Refining	Screening / Cleaning	Bleaching	Other							
Subt Area (kton, TBtu)	4,680	2.5	33.8	1.6	10.7	-				48.7	TBtu		10.4
SGW	1,416	0.56	8.04	0.34	2.01	-						15.5	10.9
TMP	3,264	0.54	6.86	0.34	2.42	-						33.2	10.2
RECYCLED PULP				Recycling									
Subt Area (kton, TBtu)	28,509			64.8						64.8	TBtu		2.3
OCC	16,683			2.11								35.2	2.1
MOW, non deinked (tissue)	3,658			2.32								8.5	2.3
ONP, deinked	4,442			3.06								13.6	3.1
MOW, deinked	2,021			3.38								6.8	3.4
Pulp Sub	1,705			0.38								0.6	0.4
Subtotal	86,437									707.9		707.9	8.2
PAPER MACHINE		Wet End	Pressing	Dryers, drying	Dry End / Calender		Coating, Prp & Dry	Super Calender					
Subt Area (kton, TBtu)	99,545	210.9	36.5	480.6	18.4		21.5	8.0		776.0	TBtu		7.8
Corrugating Medium	9,806	2.63	0.38	4.90	-		-	-				77.5	7.9
Linerboard	23,509	2.76	0.48	5.04	0.26		-	-				200.8	8.5
Recycled Board	2,061	2.66	0.41	4.92	0.24		-	-				16.9	8.2
Folding Boxboard	4,728	2.34	0.38	4.91	0.24		1.02	0.28				43.4	9.2
Gypsum Board	1,429	2.69	0.38	4.92	0.24		-	-				11.8	8.2
Bl. Folding Boxboard / Milk	6,346	2.42	0.39	4.86	0.27		1.02	0.35				59.2	9.3
Other Board, unbl	247	2.44	0.38	4.45	0.26		0.65	0.35				2.1	8.5
Kraft Paper	1,545	2.38	0.38	4.67	0.27		-	-				11.9	7.7
Special Industrial	2,323	2.37	0.38	4.67	0.27		-	-				17.9	7.7
Unctd Free, Brist, & Bl Pkg	14,069	2.43	0.39	4.86	0.27		-	-				111.9	8.0
Coated Freesheet	4,481	2.38	0.39	4.47	0.26		1.07	0.45				40.5	9.0
Newsprint	5,784	1.88	0.36	4.07	0.23		-	-				37.8	6.5
Gwd Specialties	1,668	1.88	0.36	4.07	0.23		-	-				10.9	6.5
Coated Groundwood	4,481	1.68	0.34	4.08	0.17		1.17	0.50				35.6	8.0
Tissue / Towel	7,127	0.94	0.22	7.46	-		-	-				61.5	8.6
Other Specialties	83	2.32	0.36	5.06	0.27		-	-				0.7	8.0
Market Pulp	9,858	0.14	0.14	3.35	-		-	-				35.7	3.6
Subtotal	99,545									776.0		776.0	7.8
Wastewater (WWT)	99,545	0.67								67.1		67.1	0.7
Other Utilities	99,545	0.55								55.1		55.1	0.6
Subtotal	99,545									122.2		122.2	1.2
Total	99,545									1,606.1		1,606.1	16.1

BAT Steam

		detail in MMBtu/ton								Steam TBtu		Steam TBtu	Steam MMBtu/ton
CHEMICAL PULP	Prodn (Kton/yr)	Wood Prep	Cooking	Screening / Cleaning	Washing	Evap	Lime Kiln / Chem P	Bleaching	Other				
Subt Area (kton, TBtu)	53,248	5.4	82.7	-	-	159.8	5.6	34.8	-	288.4	TBtu		5.4
Sulfite	532	0.25	2.52			2.17	0.60	2.10				4.1	7.6
Kraft, UnBleached	19,917	0.10	1.42			3.04	0.10					92.8	4.7
Kraft, Bleached, SW	13,848	0.10	1.77			2.96	0.10	1.41				87.8	6.3
Kraft, Bleached, HW	15,404	0.10	1.42			3.04	0.10	0.92				86.0	5.6
NSSC, SemiChem	3,547	0.10	1.90			2.90	0.10					17.7	5.0
MECHANICAL PULP		Wood Prep	Grinding / Refining	Screening / Cleaning	Bleaching	Other							
Subt Area (kton, TBtu)	4,680	0.3	(1.1)	-	7.0	-				6.1	TBtu		1.3
SGW	1,416		2.70		0.30							4.2	3.0
TMP	3,264	0.10	(1.52)		2.00							1.9	0.6
RECYCLED PULP				Recycling									
Subt Area (kton, TBtu)	28,509			20.8						20.8	TBtu		0.7
OCC	16,683			0.60								10.0	0.6
MOW, non deinked (tissue)	3,658			0.60								2.2	0.6
ONP, deinked	4,442			1.33								5.9	1.3
MOW, deinked	2,021			1.33								2.7	1.3
Pulp Sub	1,705			-								-	-
Subtotal	86,437									315.3		315.3	3.6
PAPER MACHINE		Wet End	Pressing	Dryers, drying	Dry End / Calender		Coating, Prep	Super Cal, heat					
Subt Area (kton, TBtu)	99,545	38.8	-	300.3	-		2.5	4.8		346.5	TBtu		3.5
Corrugating Medium	9,806	0.40		2.68								30.2	3.1
Linerboard	23,509	0.40		2.68								72.4	3.1
Recycled Board	2,061	0.40		3.60								8.2	4.0
Folding Boxboard	4,728	0.40		3.60			0.10	0.23				20.5	4.3
Gypsum Board	1,429	0.40		3.60								5.7	4.0
Bl. Folding Boxboard / Milk	6,346	0.40		2.68			0.10	0.23				21.6	3.4
Other Board, unbl	247	0.40		3.25			0.10	0.23				1.0	4.0
Kraft Paper	1,545	0.40		2.68								4.8	3.1
Special Industrial	2,323	0.40		2.68								7.2	3.1
Unctd Free, Brist, & Bl Pkg	14,069	0.40		3.76								58.5	4.2
Coated Freesheet	4,481	0.40		3.10			0.10	0.23				17.2	3.8
Newsprint	5,784	0.40		2.92								19.2	3.3
Gwd Specialties	1,668	0.40		3.56								6.6	4.0
Coated Groundwood	4,481	0.40		3.57			0.20	0.27				19.9	4.4
Tissue / Towel	7,127	0.26		3.70								28.2	4.0
Other Specialties	83	0.40		3.60								0.3	4.0
Market Pulp	9,858	0.40		2.13								24.9	2.5
Subtotal	99,545									346.5		346.5	3.5
Wastewater (WWT)	99,545	0.55								54.6		54.6	0.5
Other Utilities	99,545	0.40								39.8		39.8	0.4
Subtotal	99,545									94.4		94.4	0.9
Total	99,545									756.1		756.1	7.6

BAT Electricity

		detail in kWh/ton								Electric TBtu		Electric TBtu	Electric MMBtu/ton
CHEMICAL PULP	Prodn (Kton/yr)	Wood Prep	Cooking	Screening / Cleaning	Washing	Evap	Lime Kiln / Chem P	Bleaching	Other				
Subt Area (kton, TBtu)	53,248	10.8	18.4	2.1	1.0	11.3	5.5	11.6	-	60.8	TBtu		1.1
Sulfite	532	75.0	135.0			50.7		145.0				0.7	1.4
Kraft, UnBleached	19,917	63.0	85.0	18.0	9.0	67.0	27.0					18.3	0.9
Kraft, Bleached, SW	13,848	48.0	78.0	18.0	9.0	54.0	33.0	123.0				17.2	1.2
Kraft, Bleached, HW	15,404	63.0	85.0	-		67.0	27.0	105.0				18.2	1.2
NSSC, SemiChem	3,547	70.0	352.4			45.0	60.0					6.4	1.8
MECHANICAL PULP		Wood Prep	Grinding / Refining	Screening / Cleaning	Bleaching	Other							
Subt Area (kton, TBtu)	4,680	0.8	29.3	1.6	1.9	-				33.6	TBtu		7.2
SGW	1,416	70.0	1,842.9	100.0	120.0							10.3	7.3
TMP	3,264	41.0	1,827.0	100.0	120.0							23.3	7.1
RECYCLED PULP				Recycling									
Subt Area (kton, TBtu)	28,509			25.9						25.9	TBtu		0.9
OCC	16,683			206.0								11.7	0.7
MOW, non deinked (tissue)	3,658			348.0								4.3	1.2
ONP, deinked	4,442			395.0								6.0	1.3
MOW, deinked	2,021			472.0								3.3	1.6
Pulp Sub	1,705			104.3								0.6	0.4
Subtotal	86,437									120.3		120.3	1.4
PAPER MACHINE		Wet End	Pressing	Dryers, drying	Dry End / Calender		Coating, Prep	Super Cal, drive					
Subt Area (kton, TBtu)	99,545	56.3	31.4	39.9	17.6		1.2	2.8		149.2	TBtu		1.5
Corrugating Medium	9,806	277.0	100.0	95.0								15.8	1.6
Linerboard	23,509	172.0	120.0	105.0	75.0							37.9	1.6
Recycled Board	2,061	100.0	70.0	75.0	70.0							2.2	1.1
Folding Boxboard	4,728	100.0	70.0	75.0	70.0		10.0	30.0				5.7	1.2
Gypsum Board	1,429	100.0	70.0	75.0	70.0							1.5	1.1
Bl. Folding Boxboard / Milk	6,346	172.0	120.0	105.0	75.0		10.0	30.0				11.1	1.7
Other Board, unbl	247	172.0	100.0	85.0	75.0		10.0	30.0				0.4	1.6
Kraft Paper	1,545	172.0	120.0	105.0	75.0							2.5	1.6
Special Industrial	2,323	172.0	120.0	105.0	75.0							3.7	1.6
Unctd Free, Brist, & Bl Pkg	14,069	195.0	100.0	85.0	80.0							22.1	1.6
Coated Freesheet	4,481	185.0	95.0	85.0	70.0		25.0	40.0				7.6	1.7
Newsprint	5,784	138.0	80.0	60.0	50.0							6.5	1.1
Gwd Specialties	1,668	138.0	80.0	60.0	50.0							1.9	1.1
Coated Groundwood	4,481	250.0	100.0	65.0	50.0		25.0	65.0				8.5	1.9
Tissue / Towel	7,127	140.0	40.0	489.0								16.3	2.3
Other Specialties	83	172.0	120.0	100.0	75.0							0.1	1.6
Market Pulp	9,858	40.0	40.0	80.0								5.4	0.5
Subtotal	99,545									149.2		149.2	1.5
Wastewater (WWT)	99,545	36.9								12.5		12.5	0.1
Other Utilities	99,545	45.0								15.3		15.3	0.2
Subtotal	99,545									27.8		27.8	0.3
Total	99,545									297.3		297.3	3.0

BAT Direct Fuel

		detail in MMBtu/ton								Dr Fuel TBtu		Dr Fuel TBtu	Dr Fuel MMBtu/ton
CHEMICAL PULP	Prodn (Kton/yr)	Wood Prep	Cooking	Screening / Cleaning	Washing	Evap	Lime Kiln / Chem P	Bleaching	Other				
Subt Area (kton, TBtu)	53,248	-	-	-	-	-	72.7	-	-	72.7	TBtu		1.4
Sulfite	532						1.76					0.9	1.8
Kraft, UnBleached	19,917						1.48					29.5	1.5
Kraft, Bleached, SW	13,848						1.37					19.0	1.4
Kraft, Bleached, HW	15,404						1.25					19.3	1.3
NSSC, SemiChem	3,547						1.15					4.1	1.2
MECHANICAL PULP		Wood Prep	Grinding / Refining	Screening / Cleaning	Bleaching	Other							
Subt Area (kton, TBtu)	4,680	-	-	-	-	-				-	TBtu		-
SGW	1,416											-	-
TMP	3,264											-	-
RECYCLED PULP				Recycling									
Subt Area (kton, TBtu)	28,509			-						-	TBtu		-
OCC	16,683											-	-
MOW, non deinked (tissue)	3,658											-	-
ONP, deinked	4,442											-	-
MOW, deinked	2,021											-	-
Pulp Sub	1,705											-	-
Subtotal	86,437									72.7		72.7	0.8
PAPER MACHINE		Wet End	Pressing	Dryers, drying	Dry End / Calender		Coating, Drying	Super Cal, heat					
Subt Area (kton, TBtu)	99,545	-	-	13.2	-		17.7	-		31.0	TBtu		0.3
Corrugating Medium	9,806											-	-
Linerboard	23,509											-	-
Recycled Board	2,061											-	-
Folding Boxboard	4,728			-			0.9					4.2	0.9
Gypsum Board	1,429											-	-
Bl, Folding Boxboard / Milk	6,346						0.9					5.6	0.9
Other Board, unbl	247						0.4					0.1	0.4
Kraft Paper	1,545											-	-
Special Industrial	2,323											-	-
Unctd Free, Brist, & Bl Pkg	14,069											-	-
Coated Freesheet	4,481			-			0.9					3.9	0.9
Newsprint	5,784											-	-
Gwd Specialties	1,668			-								-	-
Coated Groundwood	4,481			-			0.9					3.9	0.9
Tissue / Towel	7,127			1.9								13.2	1.9
Other Specialties	83											-	-
Market Pulp	9,858											-	-
Subtotal	99,545									31.0		31.0	0.3
Wastewater (WWT)	99,545									-		-	-
Other Utilities	99,545									-		-	-
Subtotal	99,545									-		-	-
Total	99,545									103.7		103.7	1.0

BAT Stm + Elec + D Fuel

		detail in MMBtu/ton								All TBtu		All TBtu	All MMBtu/ton
CHEMICAL PULP	Prodn (Kton/yr)	Wood Prep	Cooking	Screening / Cleaning	Washing	Evap	Lime Kiln / Chem P	Bleaching	Other				
Subt Area (kton, TBtu)	53,248	16.2	101.2	2.1	1.0	171.1	83.8	46.4	-	421.9	TBtu		7.9
Sulfite	532	0.51	2.98	-	-	2.34	2.36	2.59	-			5.7	10.8
Kraft, UnBleached	19,917	0.31	1.71	0.06	0.03	3.27	1.67	-	-			140.6	7.1
Kraft, Bleached, SW	13,848	0.26	2.04	0.06	0.03	3.14	1.58	1.83	-			123.9	8.9
Kraft, Bleached, HW	15,404	0.31	1.71	-	-	3.27	1.44	1.28	-			123.4	8.0
NSSC, SemiChem	3,547	0.34	3.10	-	-	3.05	1.45	-	-			28.2	7.9
MECHANICAL PULP		Wood Prep	Grinding / Refining	Screening / Cleaning	Bleaching	Other							
Subt Area (kton, TBtu)	4,680	1.1	28.1	1.6	8.9	-				39.7	TBtu		8.5
SGW	1,416	0.24	8.99	0.34	0.71	-						14.6	10.3
TMP	3,264	0.24	4.71	0.34	2.41	-						25.1	7.7
RECYCLED PULP				Recycling									
Subt Area (kton, TBtu)	28,509			46.7						46.7	TBtu		1.6
OCC	16,683			1.30								21.7	1.3
MOW, non deinked (tissue)	3,658			1.79								6.5	1.8
ONP, deinked	4,442			2.68								11.9	2.7
MOW, deinked	2,021			2.94								5.9	2.9
Pulp Sub	1,705			0.36								0.6	0.4
Subtotal	86,437									508.3		508.3	5.9
PAPER MACHINE		Wet End	Pressing	Dryers, drying	Dry End / Calender		Coating, Prp & Dry	Super Calender					
Subt Area (kton, TBtu)	99,545	95.1	31.4	353.5	17.6		21.4	7.6		526.6	TBtu		5.3
Corrugating Medium	9,806	1.35	0.34	3.00	-		-	-				46.0	4.7
Linerboard	23,509	0.99	0.41	3.04	0.26		-	-				110.3	4.7
Recycled Board	2,061	0.74	0.24	3.86	0.24		-	-				10.5	5.1
Folding Boxboard	4,728	0.74	0.24	3.86	0.24		1.01	0.33				30.4	6.4
Gypsum Board	1,429	0.74	0.24	3.86	0.24		-	-				7.3	5.1
Bl. Folding Boxboard / Milk	6,346	0.99	0.41	3.04	0.26		1.01	0.33				38.3	6.0
Other Board, unbl	247	0.99	0.34	3.54	0.26		0.53	0.33				1.5	6.0
Kraft Paper	1,545	0.99	0.41	3.04	0.26		-	-				7.2	4.7
Special Industrial	2,323	0.99	0.41	3.04	0.26		-	-				10.9	4.7
Unctd Free, Brist, & Bl Pkg	14,069	1.07	0.34	4.05	0.27		-	-				80.6	5.7
Coated Freesheet	4,481	1.03	0.32	3.39	0.24		1.07	0.37				28.8	6.4
Newsprint	5,784	0.87	0.27	3.12	0.17		-	-				25.7	4.4
Gwd Specialties	1,668	0.87	0.27	3.76	0.17		-	-				8.5	5.1
Coated Groundwood	4,481	1.25	0.34	3.79	0.17		1.17	0.49				32.3	7.2
Tissue / Towel	7,127	0.74	0.14	7.23	-		-	-				57.7	8.1
Other Specialties	83	0.99	0.41	3.94	0.26		-	-				0.5	5.6
Market Pulp	9,858	0.54	0.14	2.40	-		-	-				30.3	3.1
Subtotal	99,545									526.6		526.6	5.3
Wastewater (WWT)	99,545	0.67								67.1		67.1	0.7
Other Utilities	99,545	0.55								55.1		55.1	0.6
Subtotal	99,545									122.2		122.2	1.2
Total	99,545									1,157.1		1,157.1	11.6

Prac Min Steam

		detail in MMBtu/ton								Steam TBtu		Steam TBtu	Steam MMBtu/ton
CHEMICAL PULP	Prodn (Kton/yr)	Wood Prep	Cooking	Screening / Cleaning	Washing	Evap	Lime Kiln / Chem P	Bleaching	Other				
Subt Area (kton, TBtu)	53,248	5.4	82.7	-	-	117.1	5.6	34.8	-	245.7	TBtu		4.6
Sulfite	532	0.25	2.52			1.59	0.60	2.10				3.8	7.1
Kraft, UnBleached	19,917	0.10	1.42			2.23	0.10					76.6	3.8
Kraft, Bleached, SW	13,848	0.10	1.77			2.17	0.10	1.41				76.9	5.5
Kraft, Bleached, HW	15,404	0.10	1.42			2.23	0.10	0.92				73.5	4.8
NSSC, SemiChem	3,547	0.10	1.90			2.13	0.10					15.0	4.2
MECHANICAL PULP		Wood Prep	Grinding / Refining	Screening / Cleaning	Bleaching	Other							
Subt Area (kton, TBtu)	4,680	0.3	(1.1)	-	7.0	-				6.1	TBtu		1.3
SGW	1,416		2.70		0.30							4.2	3.0
TMP	3,264	0.10	(1.52)		2.00							1.9	0.6
RECYCLED PULP				Recycling									
Subt Area (kton, TBtu)	28,509			20.8						20.8	TBtu		0.7
OCC	16,683			0.60								10.0	0.6
MOW, non deinked (tissue)	3,658			0.60								2.2	0.6
ONP, deinked	4,442			1.33								5.9	1.3
MOW, deinked	2,021			1.33								2.7	1.3
Pulp Sub	1,705			-								-	-
Subtotal	86,437									272.6		272.6	3.2
PAPER MACHINE		Wet End	Pressing	Dryers, Drying	Dry End / Calender		Coating, Prep	Super Cal, heat					
Subt Area (kton, TBtu)	99,545	38.8	-	102.7	-		2.5	4.8		148.9	TBtu		1.5
Corrugating Medium	9,806	0.40		0.92								12.9	1.3
Linerboard	23,509	0.40		0.92								31.0	1.3
Recycled Board	2,061	0.40		1.23								3.4	1.6
Folding Boxboard	4,728	0.40		1.23			0.10	0.23				9.3	2.0
Gypsum Board	1,429	0.40		1.23								2.3	1.6
Bl. Folding Boxboard / Milk	6,346	0.40		0.92			0.10	0.23				10.4	1.6
Other Board, unbl	247	0.40		1.11			0.10	0.23				0.5	1.8
Kraft Paper	1,545	0.40		0.92								2.0	1.3
Special Industrial	2,323	0.40		0.92								3.1	1.3
Unctd Free, Brist, & Bl Pkg	14,069	0.40		1.29								23.7	1.7
Coated Freesheet	4,481	0.40		1.06			0.10	0.23				8.0	1.8
Newsprint	5,784	0.40		1.00								8.1	1.4
Gwd Specialties	1,668	0.40		1.22								2.7	1.6
Coated Groundwood	4,481	0.40		1.22			0.20	0.27				9.4	2.1
Tissue / Towel	7,127	0.26		1.27								10.9	1.5
Other Specialties	83	0.40		1.23								0.1	1.6
Market Pulp	9,858	0.40		0.73								11.1	1.1
Subtotal	99,545									148.9		148.9	1.5
Wastewater (WWT)	99,545	0.55								54.6		54.6	0.5
Other Utilities	99,545	0.40								39.8		39.8	0.4
Subtotal	99,545									94.4		94.4	0.9
Total	99,545									515.9		515.9	5.2

Prac Min Electricity

		detail in kWh/ton								Electric TBtu		Electric TBtu	Electric MMBtu/ton
CHEMICAL PULP	Prodn (Kton/yr)	Wood Prep	Cooking	Screening / Cleaning	Washing	Evap	Lime Kiln / Chem P	Bleaching	Other				
Subt Area (kton, TBtu)	53,248	10.8	18.4	2.1	1.0	11.3	5.5	11.6	-	60.8	TBtu		1.1
Sulfite	532	75.0	135.0			50.7		145.0				0.7	1.4
Kraft, UnBleached	19,917	63.0	85.0	18.0	9.0	67.0	27.0					18.3	0.9
Kraft, Bleached, SW	13,848	48.0	78.0	18.0	9.0	54.0	33.0	123.0				17.2	1.2
Kraft, Bleached, HW	15,404	63.0	85.0	-		67.0	27.0	105.0				18.2	1.2
NSSC, SemiChem	3,547	70.0	352.4			45.0	60.0					6.4	1.8
MECHANICAL PULP		Wood Prep	Grinding / Refining	Screening / Cleaning	Bleaching	Other							
Subt Area (kton, TBtu)	4,680	0.8	29.3	1.6	1.9	-				33.6	TBtu		7.2
SGW	1,416	70.0	1,842.9	100.0	120.0							10.3	7.3
TMP	3,264	41.0	1,827.0	100.0	120.0							23.3	7.1
RECYCLED PULP				Recycling									
Subt Area (kton, TBtu)	28,509			25.9						25.9	TBtu		0.9
OCC	16,683			206.0								11.7	0.7
MOW, non deinked (tissue)	3,658			348.0								4.3	1.2
ONP, deinked	4,442			395.0								6.0	1.3
MOW, deinked	2,021			472.0								3.3	1.6
Pulp Sub	1,705			104.3								0.6	0.4
Subtotal	86,437									120.3		120.3	1.4
PAPER MACHINE		Wet End	Pressing	Dryers, Drying	Dry End / Calender		Coating, Prep	Super Cal, drive					
Subt Area (kton, TBtu)	99,545	56.3	31.4	39.9	17.6		1.2	2.8		149.2	TBtu		1.5
Corrugating Medium	9,806	277.0	100.0	95.0								15.8	1.6
Linerboard	23,509	172.0	120.0	105.0	75.0							37.9	1.6
Recycled Board	2,061	100.0	70.0	75.0	70.0							2.2	1.1
Folding Boxboard	4,728	100.0	70.0	75.0	70.0		10.0	30.0				5.7	1.2
Gypsum Board	1,429	100.0	70.0	75.0	70.0							1.5	1.1
Bl. Folding Boxboard / Milk	6,346	172.0	120.0	105.0	75.0		10.0	30.0				11.1	1.7
Other Board, unbl	247	172.0	100.0	85.0	75.0		10.0	30.0				0.4	1.6
Kraft Paper	1,545	172.0	120.0	105.0	75.0							2.5	1.6
Special Industrial	2,323	172.0	120.0	105.0	75.0							3.7	1.6
Unctd Free, Brist, & Bl Pkg	14,069	195.0	100.0	85.0	80.0							22.1	1.6
Coated Freesheet	4,481	185.0	95.0	85.0	70.0		25.0	40.0				7.6	1.7
Newsprint	5,784	138.0	80.0	60.0	50.0							6.5	1.1
Gwd Specialties	1,668	138.0	80.0	60.0	50.0							1.9	1.1
Coated Groundwood	4,481	250.0	100.0	65.0	50.0		25.0	65.0				8.5	1.9
Tissue / Towel	7,127	140.0	40.0	489.0								16.3	2.3
Other Specialties	83	172.0	120.0	100.0	75.0							0.1	1.6
Market Pulp	9,858	40.0	40.0	80.0								5.4	0.5
Subtotal	99,545									149.2		149.2	1.5
Wastewater (WWT)	99,545	36.9								12.5		12.5	0.1
Other Utilities	99,545	45.0								15.3		15.3	0.2
Subtotal	99,545									27.8		27.8	0.3
Total	99,545									297.3		297.3	3.0

Prac Min Direct Fuel

		detail in MMBtu/ton								Dr Fuel TBtu		Dr Fuel TBtu	Dr Fuel MMBtu/ton
CHEMICAL PULP	Prodn (Kton/yr)	Wood Prep	Cooking	Screening / Cleaning	Washing	Evap	Lime Kiln / Chem P	Bleaching	Other				
Subt Area (kton, TBtu)	53,248	-	-	-	-	-	47.6	-	-	47.6	TBtu		0.9
Sulfite	532						1.76					0.9	1.8
Kraft, UnBleached	19,917						0.96					19.2	1.0
Kraft, Bleached, SW	13,848						0.89					12.3	0.9
Kraft, Bleached, HW	15,404						0.81					12.5	0.8
NSSC, SemiChem	3,547						0.75					2.7	0.7
MECHANICAL PULP		Wood Prep	Grinding / Refining	Screening / Cleaning	Bleaching	Other							
Subt Area (kton, TBtu)	4,680	-	-	-	-	-				-	TBtu		-
SGW	1,416											-	-
TMP	3,264											-	-
RECYCLED PULP				Recycling									
Subt Area (kton, TBtu)	28,509			-						-	TBtu		-
OCC	16,683											-	-
MOW, non deinked (tissue)	3,658											-	-
ONP, deinked	4,442											-	-
MOW, deinked	2,021											-	-
Pulp Sub	1,705											-	-
Subtotal	86,437									47.6		47.6	0.6
PAPER MACHINE		Wet End	Pressing	Dryers, Drying	Dry End / Calender		Coating, Drying	Super Cal, heat					
Subt Area (kton, TBtu)	99,545	-	-	13.2	-		17.7			31.0	TBtu		0.3
Corrugating Medium	9,806											-	-
Linerboard	23,509											-	-
Recycled Board	2,061											-	-
Folding Boxboard	4,728			-			0.9					4.2	0.9
Gypsum Board	1,429											-	-
Bl. Folding Boxboard / Milk	6,346						0.9					5.6	0.9
Other Board, unbl	247						0.4					0.1	0.4
Kraft Paper	1,545											-	-
Special Industrial	2,323											-	-
Unctd Free, Brist, & Bl Pkg	14,069											-	-
Coated Freesheet	4,481			-			0.9					3.9	0.9
Newsprint	5,784											-	-
Gwd Specialties	1,688			-								-	-
Coated Groundwood	4,481			-			0.9					3.9	0.9
Tissue / Towel	7,127			1.9								13.2	1.9
Other Specialties	83											-	-
Market Pulp	9,858											-	-
Subtotal	99,545									31.0		31.0	0.3
Wastewater (WWT)	99,545									-		-	-
Other Utilities	99,545									-		-	-
Subtotal	99,545									-		-	-
Total	99,545									78.6		78.6	0.8

Prac Min Stm + Elec + D Fuel

		detail in MMBtu/ton								All	All	All
	Prodn	Wood		Screening			Lime Kiln /			TBtu	TBtu	MMBtu/ton
CHEMICAL PULP	(Kton/yr)	Prep	Cooking	/ Cleaning	Washing	Evap	Chem P	Bleaching	Other			
Subt Area (kton, TBtu)	53,248	16.2	101.2	2.1	1.0	128.4	58.7	46.4	-	354.1	TBtu	6.6
Sulfite	532	0.51	2.98	-	-	1.76	2.36	2.59	-		5.4	10.2
Kraft, UnBleached	19,917	0.31	1.71	0.06	0.03	2.46	1.15	-	-		114.1	5.7
Kraft, Bleached, SW	13,848	0.26	2.04	0.06	0.03	2.35	1.10	1.83	-		106.3	7.7
Kraft, Bleached, HW	15,404	0.31	1.71	-	-	2.46	1.00	1.28	-		104.2	6.8
NSSC, SemiChem	3,547	0.34	3.10	-	-	2.28	1.05	-	-		24.0	6.8
		Wood	Grinding /	Screening								
MECHANICAL PULP		Prep	Refining	/ Cleaning	Bleaching	Other						
Subt Area (kton, TBtu)	4,680	1.1	28.1	1.6	8.9	-				39.7	TBtu	8.5
SGW	1,416	0.24	8.99	0.34	0.71	-					14.6	10.3
TMP	3,264	0.24	4.71	0.34	2.41	-					25.1	7.7
RECYCLED PULP				Recycling								
Subt Area (kton, TBtu)	28,509			46.7						46.7	TBtu	1.6
OCC	16,683			1.30							21.7	1.3
MOW, non deinked (tissue)	3,658			1.79							6.5	1.8
ONP, deinked	4,442			2.68							11.9	2.7
MOW, deinked	2,021			2.94							5.9	2.9
Pulp Sub	1,705			0.36							0.6	0.4
Subtotal	86,437									440.5	440.5	5.1
				Dryers,	Dry End /		Coating,	Super				
PAPER MACHINE		Wet End	Pressing	Drying	Calender		Prp & Dry	Calender				
Subt Area (kton, TBtu)	99,545	95.1	31.4	155.9	17.6		21.4	7.6		329.0	TBtu	3.3
Corrugating Medium	9,806	1.35	0.34	1.24	-		-	-			28.7	2.9
Linerboard	23,509	0.99	0.41	1.27	0.26		-	-			68.8	2.9
Recycled Board	2,061	0.74	0.24	1.49	0.24		-	-			5.6	2.7
Folding Boxboard	4,728	0.74	0.24	1.49	0.24		1.01	0.33			19.2	4.1
Gypsum Board	1,429	0.74	0.24	1.49	0.24		-	-			3.9	2.7
Bl. Folding Boxboard / Milk	6,346	0.99	0.41	1.27	0.26		1.01	0.33			27.1	4.3
Other Board, unbl	247	0.99	0.34	1.40	0.26		0.53	0.33			0.9	3.8
Kraft Paper	1,545	0.99	0.41	1.27	0.26		-	-			4.5	2.9
Special Industrial	2,323	0.99	0.41	1.27	0.26		-	-			6.8	2.9
Unctd Free, Brist, & Bl Pkg	14,069	1.07	0.34	1.58	0.27		-	-			45.8	3.3
Coated Freesheet	4,481	1.03	0.32	1.35	0.24		1.07	0.37			19.6	4.4
Newsprint	5,784	0.87	0.27	1.20	0.17		-	-			14.6	2.5
Gwd Specialties	1,668	0.87	0.27	1.42	0.17		-	-			4.6	2.7
Coated Groundwood	4,481	1.25	0.34	1.44	0.17		1.17	0.49			21.8	4.9
Tissue / Towel	7,127	0.74	0.14	4.79	-		-	-			40.4	5.7
Other Specialties	83	0.99	0.41	1.57	0.26		-	-			0.3	3.2
Market Pulp	9,858	0.54	0.14	1.00	-		-	-			16.5	1.7
Subtotal	99,545									329.0	329.0	3.3
Wastewater (WWT)	99,545	0.67								67.1	67.1	0.7
Other Utilities	99,545	0.55								55.1	55.1	0.6
Subtotal	99,545									122.2	122.2	1.2
Total	99,545									891.7	891.7	9.0

Theo Min Steam		detail in MMBtu/ton								Steam TBtu		Steam MMBtu/ton
CHEMICAL PULP	Prodn (Kton/yr)	Wood Prep	Cooking	Screening / Cleaning	Washing	Evap	Lime Kiln / Chem P	Bleaching	Other			
Subt Area (kton, TBtu)	53,248	5.4	82.7	-	-	101.2	5.6	34.8	-	229.7	TBtu	4.3
Sulfite	532	0.25	2.52			1.37	0.60	2.10			3.6	6.8
Kraft, UnBleached	19,917	0.10	1.42			1.92	0.10				70.6	3.5
Kraft, Bleached, SW	13,848	0.10	1.77			1.87	0.10	1.41			72.8	5.3
Kraft, Bleached, HW	15,404	0.10	1.42			1.92	0.10	0.92			68.8	4.5
NSSC, SemiChem	3,547	0.10	1.90			1.84	0.10				14.0	3.9
MECHANICAL PULP		Wood Prep	Grinding / Refining	Screening / Cleaning	Bleaching	Other						
Subt Area (kton, TBtu)	4,680	0.3	(1.1)	-	7.0	-				6.1	TBtu	1.3
SGW	1,416		2.70		0.30						4.2	3.0
TMP	3,264	0.10	(1.52)		2.00						1.9	0.6
RECYCLED PULP				Recycling								
Subt Area (kton, TBtu)	28,509			20.8						20.8	TBtu	0.7
OCC	16,683			0.60							10.0	0.6
MOW, non deinked (tissue)	3,658			0.60							2.2	0.6
ONP, deinked	4,442			1.33							5.9	1.3
MOW, deinked	2,021			1.33							2.7	1.3
Pulp Sub	1,705			-							-	-
Subtotal	86,437									256.7	256.7	3.0
PAPER MACHINE		Wet End	Pressing	Dryers, Drying	Dry End / Calender		Coating, Prep	Super Cal, heat				
Subt Area (kton, TBtu)	99,545	38.8	-	71.2	-		2.5	4.8		117.3	TBtu	1.2
Corrugating Medium	9,806	0.40		0.64							10.2	1.0
Linerboard	23,509	0.40		0.64							24.3	1.0
Recycled Board	2,061	0.40		0.85							2.6	1.3
Folding Boxboard	4,728	0.40		0.85			0.10	0.23			7.5	1.6
Gypsum Board	1,429	0.40		0.85							1.8	1.3
Bl. Folding Boxboard / Milk	6,346	0.40		0.64			0.10	0.23			8.7	1.4
Other Board, unbl	247	0.40		0.77			0.10	0.23			0.4	1.5
Kraft Paper	1,545	0.40		0.64							1.6	1.0
Special Industrial	2,323	0.40		0.64							2.4	1.0
Unctd Free, Brist, & Bl Pkg	14,069	0.40		0.89							18.2	1.3
Coated Freesheet	4,481	0.40		0.73			0.10	0.23			6.6	1.5
Newsprint	5,784	0.40		0.69							6.3	1.1
Gwd Specialties	1,668	0.40		0.84							2.1	1.2
Coated Groundwood	4,481	0.40		0.85			0.20	0.27			7.7	1.7
Tissue / Towel	7,127	0.26		0.88							8.1	1.1
Other Specialties	83	0.40		0.85							0.1	1.3
Market Pulp	9,858	0.40		0.50							8.9	0.9
Subtotal	99,545									117.3	117.3	1.2
Wastewater (WWT)	99,545	0.55								54.6	54.6	0.5
Other Utilities	99,545	0.40								39.8	39.8	0.4
Subtotal	99,545									94.4	94.4	0.9
Total	99,545									468.3	468.3	4.7

Theo Min Electricity

		detail in kWh/ton								Electric TBtu		Electric TBtu	Electric MMBtu/ton
CHEMICAL PULP	Prodn (Kton/yr)	Wood Prep	Cooking	Screening / Cleaning	Washing	Evap	Lime Kiln / Chem P	Bleaching	Other				
Subt Area (kton, TBtu)	53,248	10.8	18.4	2.1	1.0	11.3	5.5	11.6	-	60.8	TBtu		1.1
Sulfite	532	75.0	135.0			50.7		145.0				0.7	1.4
Kraft, UnBleached	19,917	63.0	85.0	18.0	9.0	67.0	27.0					18.3	0.9
Kraft, Bleached, SW	13,848	48.0	78.0	18.0	9.0	54.0	33.0	123.0				17.2	1.2
Kraft, Bleached, HW	15,404	63.0	85.0	-		67.0	27.0	105.0				18.2	1.2
NSSC, SemiChem	3,547	70.0	352.4			45.0	60.0					6.4	1.8
MECHANICAL PULP		Wood Prep	Grinding / Refining	Screening / Cleaning	Bleaching	Other							
Subt Area (kton, TBtu)	4,680	0.8	29.3	1.6	1.9	-				33.6	TBtu		7.2
SGW	1,416	70.0	1,842.9	100.0	120.0							10.3	7.3
TMP	3,264	41.0	1,827.0	100.0	120.0							23.3	7.1
RECYCLED PULP				Recycling									
Subt Area (kton, TBtu)	28,509			25.9						25.9	TBtu		0.9
OCC	16,683			206.0								11.7	0.7
MOW, non deinked (tissue)	3,658			348.0								4.3	1.2
ONP, deinked	4,442			395.0								6.0	1.3
MOW, deinked	2,021			472.0								3.3	1.6
Pulp Sub	1,705			104.3								0.6	0.4
Subtotal	86,437									120.3		120.3	1.4
PAPER MACHINE		Wet End	Pressing	Dryers, Drying	Dry End / Calender		Coating, Prep	Super Cal, drive					
Subt Area (kton, TBtu)	99,545	56.3	31.4	39.9	17.6		1.2	2.8		149.2	TBtu		1.5
Corrugating Medium	9,806	277.0	100.0	95.0								15.8	1.6
Linerboard	23,509	172.0	120.0	105.0	75.0							37.9	1.6
Recycled Board	2,061	100.0	70.0	75.0	70.0							2.2	1.1
Folding Boxboard	4,728	100.0	70.0	75.0	70.0		10.0	30.0				5.7	1.2
Gypsum Board	1,429	100.0	70.0	75.0	70.0							1.5	1.1
Bl. Folding Boxboard / Milk	6,346	172.0	120.0	105.0	75.0		10.0	30.0				11.1	1.7
Other Board, unbl	247	172.0	100.0	85.0	75.0		10.0	30.0				0.4	1.6
Kraft Paper	1,545	172.0	120.0	105.0	75.0							2.5	1.6
Special Industrial	2,323	172.0	120.0	105.0	75.0							3.7	1.6
Unctd Free, Brist, & Bl Pkg	14,069	195.0	100.0	85.0	80.0							22.1	1.6
Coated Freesheet	4,481	185.0	95.0	85.0	70.0		25.0	40.0				7.6	1.7
Newsprint	5,784	138.0	80.0	60.0	50.0							6.5	1.1
Gwd Specialties	1,668	138.0	80.0	60.0	50.0							1.9	1.1
Coated Groundwood	4,481	250.0	100.0	65.0	50.0		25.0	65.0				8.5	1.9
Tissue / Towel	7,127	140.0	40.0	489.0								16.3	2.3
Other Specialties	83	172.0	120.0	100.0	75.0							0.1	1.6
Market Pulp	9,858	40.0	40.0	80.0								5.4	0.5
Subtotal	99,545									149.2		149.2	1.5
Wastewater (WWT)	99,545	36.9								12.5		12.5	0.1
Other Utilities	99,545	45.0								15.3		15.3	0.2
Subtotal	99,545									27.8		27.8	0.3
Total	99,545									297.3		297.3	3.0

Theo Min Direct Fuel		detail in MMBtu/ton								Dr Fuel TBtu	Dr Fuel TBtu	Dr Fuel MMBtu/ton
CHEMICAL PULP	Prodn (Kton/yr)	Wood Prep	Cooking	Screening / Cleaning	Washing	Evap	Lime Kiln / Chem P	Bleaching	Other			
Subt Area (kton, TBtu)	53,248	-	-	-	-	-	36.8	-	-	36.8	TBtu	0.7
Sulfite	532						1.76				0.9	1.8
Kraft, UnBleached	19,917						0.74				14.7	0.7
Kraft, Bleached, SW	13,848						0.69				9.5	0.7
Kraft, Bleached, HW	15,404						0.63				9.6	0.6
NSSC, SemiChem	3,547						0.58				2.0	0.6
MECHANICAL PULP		Wood Prep	Grinding / Refining	Screening / Cleaning	Bleaching	Other						
Subt Area (kton, TBtu)	4,680	-	-	-	-	-				-	TBtu	-
SGW	1,416										-	-
TMP	3,264										-	-
RECYCLED PULP				Recycling								
Subt Area (kton, TBtu)	28,509			-						-	TBtu	-
OCC	16,683										-	-
MOW, non deinked (tissue)	3,658										-	-
ONP, deinked	4,442										-	-
MOW, deinked	2,021										-	-
Pulp Sub	1,705										-	-
Subtotal	86,437									36.8	36.8	0.4
PAPER MACHINE		Wet End	Pressing	Dryers, Drying	Dry End / Calender		Coating, Drying	Super Cal, heat				
Subt Area (kton, TBtu)	99,545	-	-	13.2	-		17.7	-		31.0	TBtu	0.3
Corrugating Medium	9,806										-	-
Linerboard	23,509										-	-
Recycled Board	2,061										-	-
Folding Boxboard	4,728			-			0.9				4.2	0.9
Gypsum Board	1,429										-	-
Bl. Folding Boxboard / Milk	6,346						0.9				5.6	0.9
Other Board, unbl	247						0.4				0.1	0.4
Kraft Paper	1,545										-	-
Special Industrial	2,323										-	-
Unctd Free, Brist, & Bl Pkg	14,069										-	-
Coated Freesheet	4,481			-			0.9				3.9	0.9
Newsprint	5,784										-	-
Gwd Specialties	1,668			-							-	-
Coated Groundwood	4,481			-			0.9				3.9	0.9
Tissue / Towel	7,127			1.9							13.2	1.9
Other Specialties	83										-	-
Market Pulp	9,858										-	-
Subtotal	99,545									31.0	31.0	0.3
Wastewater (WWT)	99,545									-	-	-
Other Utilities	99,545									-	-	-
Subtotal	99,545									-	-	-
Total	99,545									67.8	67.8	0.7

Theo Min Stm + Elec + D Fuel

		detail in MMBtu/ton								All TBtu		All TBtu	All MMBtu/ton
CHEMICAL PULP	Prodn (Kton/yr)	Wood Prep	Cooking	Screening / Cleaning	Washing	Evap	Lime Kiln / Chem P	Bleaching	Other				
Subt Area (kton, TBtu)	53,248	16.2	101.2	2.1	1.0	112.4	48.0	46.4	-	327.3	TBtu		6.1
Sulfite	532	0.51	2.98	-	-	1.55	2.36	2.59	-			5.3	10.0
Kraft, UnBleached	19,917	0.31	1.71	0.06	0.03	2.15	0.93	-	-			103.6	5.2
Kraft, Bleached, SW	13,848	0.26	2.04	0.06	0.03	2.06	0.90	1.83	-			99.4	7.2
Kraft, Bleached, HW	15,404	0.31	1.71	-	-	2.15	0.82	1.28	-			96.6	6.3
NSSC, SemiChem	3,547	0.34	3.10	-	-	1.99	0.88	-	-			22.4	6.3
MECHANICAL PULP		Wood Prep	Grinding / Refining	Screening / Cleaning	Bleaching	Other							
Subt Area (kton, TBtu)	4,680	1.1	28.1	1.6	8.9	-				39.7	TBtu		8.5
SGW	1,416	0.24	8.99	0.34	0.71	-						14.6	10.3
TMP	3,264	0.24	4.71	0.34	2.41	-						25.1	7.7
RECYCLED PULP				Recycling									
Subt Area (kton, TBtu)	28,509			46.7						46.7	TBtu		1.6
OCC	16,683			1.30								21.7	1.3
MOW, non deinked (tissue)	3,658			1.79								6.5	1.8
ONP, deinked	4,442			2.68								11.9	2.7
MOW, deinked	2,021			2.94								5.9	2.9
Pulp Sub	1,705			0.36								0.6	0.4
Subtotal	86,437									413.7		413.7	4.8
PAPER MACHINE		Wet End	Pressing	Dryers, Drying	Dry End / Calender		Coating, Prp & Dry	Super Calender					
Subt Area (kton, TBtu)	99,545	95.1	31.4	124.4	17.6		21.4	7.6		297.5	TBtu		3.0
Corrugating Medium	9,806	1.35	0.34	0.96	-		-	-				25.9	2.6
Linerboard	23,509	0.99	0 41	0.99	0 26		-	-				62.2	2.6
Recycled Board	2,061	0.74	0.24	1.11	0.24		-	-				4.8	2.3
Folding Boxboard	4,728	0.74	0.24	1.11	0.24		1.01	0.33				17.4	3.7
Gypsum Board	1,429	0.74	0.24	1.11	0.24		-	-				3.3	2.3
Bl. Folding Boxboard / Milk	6,346	0.99	0.41	0 99	0.26		1.01	0.33				25.3	4.0
Other Board, unbl	247	0.99	0.34	1.06	0.26		0.53	0.33				0.9	3.5
Kraft Paper	1,545	0.99	0.41	0.99	0.26		-	-				4.1	2.6
Special Industrial	2,323	0.99	0 41	0 99	0 26		-	-				6.1	2.6
Unctd Free, Brist, & Bl Pkg	14,069	1.07	0.34	1.18	0.27		-	-				40.2	2.9
Coated Freesheet	4,481	1.03	0.32	1.02	0.24		1.07	0.37				18.2	4.1
Newsprint	5,784	0.87	0.27	0.90	0.17		-	-				12.8	2.2
Gwd Specialties	1,668	0.87	0.27	1.05	0.17		-	-				3.9	2.4
Coated Groundwood	4,481	1.25	0.34	1.07	0.17		1.17	0.49				20.1	4.5
Tissue / Towel	7 127	0.74	0.14	4.40	-		-	-				37.6	5.3
Other Specialties	83	0.99	0.41	1.19	0.26		-	-				0.2	2.8
Market Pulp	9,858	0.54	0.14	0.78	-		-	-				14.3	1.5
Subtotal	99,545									297.5		297.5	3.0
Wastewater (WWT)	99,545	0.67								67.1		67 1	0.7
Other Utilities	99,545	0.55								55.1		55.1	0.6
Subtotal	99,545									122.2		122.2	1.2
Total	99,545									833.4		833.4	8.4

Tab I - Abbreviations

Abbreviations used in pulp and paper process descriptions:

AA	Active Alkali
AD	Air Dried, i.e. at 10 % moisture
admt	Air dried metric ton, 10% moisture, 2205 pounds
adst	Air dried short ton, 10% moisture, 2000 pounds
BAD	Bleached Air Died
BD	Bone dried, i.e. at 0% moisture; same as OD, below
BOD	Biochemical oxygen demand
BLS	Black Liquor Solids
Btu	British Thermal Unit; 3412 Btus per kilowatt-hour
CaO	Calcium Oxide
cu ft, ft^3	Cubic feet
cu m, m^3	Cubic meter
cm^2	Square centimeters
G	Giga, 10^9
gpl	Grams per liter
gpm	Gallons per minute
gsm	Grams per square meter
fpm	Feet per minute
fst	Finished short ton, finished paper product, 2000 pounds
HWD	Hardwood
J	Joule
k	Kilo, 10^3
kg	Kilogram, i.e. 1000 grams
kWh	Kilowatt Hour
L/s	Liters per second
lbs	Pounds
m	Meters, metric
M	Mega, 10^6 a prefix for metric units; also thousand as prefix to English units,
MD	Machine Dried, i.e. typically 4 - 7% moisture
MDfst	Machined Dried finished short ton
MGD	Million gallons per day
Mlb	1000 pounds
MM	Million, 10^6 prefix for English units

m/min	Meters per minute
MOW	Mixed office waste
mtpd, mt/d	Metric tons per day, i.e. equal to 2205 lbs
NaOH	Caustic soda or sodium hydroxide
NSSC	Neutral Sulfite Semi-chemical (also used for green liquor semi-chemical)
O	Oxygen (O_2)
OCC	Old corrugated containers
OD	Oven Dried, i.e. at 0 % moisture, same as bone dried
ONP	Old newsprint
P	Hydrogen peroxide (H_2O_2)
psi	Pounds per square inch
Q	Chelation
sq ft, ft^2	Square feet
stm	Steam
SGW	Stone ground wood
SWD	Softwood
T	Trillion, 10^{12}
TIC	Total Installed Cost
TMP	Thermal mechanical pulp
Tpd	Tons per day, i.e. equal to 2000 lbs
Tph	Tons per hour
Tpy	Tons per year

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